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MODERN ELEMENTARY SCHOOL SCIENCE

a recommended sequence

WILLARD J. JACOBSON
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Willard J. Jacobson, *Editor*

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WILLARD J. JACOBSON
Associate Director, Science Manpower Project

HAROLD E. TANNENBAUM
Fellow of the Science Manpower Project

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EDITOR'S PREFACE

This monograph is one of a series prepared by the Science Manpower Project of Teachers College, Columbia University. Financed by a group of leading American industries and foundations established by industries, the efforts of the Science Manpower Project are directed to the improvement of science education in the schools of the nation. One phase of this effort has been the production of a series of monographs dealing with the general revision of the science program in the schools.

Modern Elementary School Science is the final volume in this series, which includes recommendations for junior high school science, and for biology, chemistry and physics in the senior high school. In preparing the present monograph, careful attention has been given to articulation with the Science Manpower Project's recommendations for science courses at the junior and senior high school levels, primarily by avoiding repetition of instruction and fostering a continuous process of concept formation.

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Elementary school science is an essential feature of modern school programs, and in the future it probably will assume an even more important role. It should be regarded as the fourth R of all elementary school instruction. The purpose of this monograph is to indicate directions for the further development of this basic introduction to science and the scientific enterprise.

What kinds of science experiences should children have in the elementary school? How can high-quality elementary science experiences be developed? What should be the characteristics of first-rate elementary school science programs in the future?

In *Modern Elementary School Science* the authors propose a two-dimensional program. In the *flexible dimension* of the program, children encounter a wide variety of experiences related to the questions they ask, to other subjects in the curriculum, to timely concerns in the community, and to special science projects which they may undertake. In the *planned dimension* of the program, high-quality experiences, developed in depth, are recommended in six major phases of science education. In addition, a set of goals is proposed for elementary school science, and criteria are suggested for planning programs. Procedures for evaluation are discussed, and suggestions are made with regard to facilities, equipment and materials.

Recommendations made by the authors are based on experience. Almost all the suggestions have been tried out somewhere and at some time, but it is unlikely that many schools have incorporated the total pattern of the recommendations in their programs.

It is also noteworthy that the recommendations and suggestions did not originate with the authors alone. Some sixty Associates of the Science Manpower Project at other colleges and universities have been consulted in the process of developing the recommended elementary science sequence. Dr. Robert Stollberg of San Francisco State College was especially generous in supplying comments and suggestions. Miss Eileen Cowe read critically the section on science in the kindergarten and the Nutrition Foundation assisted in the development of the materials on food and nutrition. Various Fellows of the Project, in residence at Teachers College, Columbia University, have also had a part in shaping the recommendations, including Dr. Louis T. Cox, Mr. J. W. Erickson, Mr. Robert N. King, Dr. Lester C. Mills, Mr. James T. Pitts, and Mr. Seymour Trieger.

Modern Elementary School Science is designed to serve two general purposes. Some schools may elect to employ the recommended program more or less as it is outlined in this monograph. Others may prefer to use it as a guide in modernizing existing curricula. In any case, it must be recognized that pupil abilities and backgrounds vary, that local school policies must be taken into account, and that available facilities, equipment, and instructional personnel are by no means uniform. These considerations make it mandatory that *any program be adapted to local circumstances.* We may also assume that the march of learning will not be halted, and that new discoveries in the weeks and months to come will merit recognition in any programs we may establish at this time.

FREDERICK L. FITZPATRICK
Head of Department of Teaching of Science
Teachers College, Columbia University

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MODERN
ELEMENTARY SCHOOL
SCIENCE

Chapter One

INTRODUCTION

The roots of elementary school science run deep into our history, and they are well anchored in the tested experiences of courageous teachers and enthusiastic children who have "experimented" with science. Elementary school science has been taught in the one room of the little red schoolhouse, in the crowded, towering school of the big city, and in the shiny classrooms of our new suburbs. We can learn from the failures and successes of others, and the elementary school science programs of the future will be built on the many trial-and-error experiences of the past.

The importance of elementary school science was recognized early in our history. Far-seeing leaders of the stature of Benjamin Franklin and Thomas Jefferson saw the importance of helping young people understand and interpret the phenomena that occur in their natural environment. They noted the practical importance of knowing basic physical and biological principles and being able to use them to improve the home, farm, business, and community. They recognized the application of these basic principles in making and using tools and machines, and in controlling conditions for the growth and use of plants and animals. These early purposes of elementary school science are still valid, and are among the guidelines for the development of effective elementary school science programs.

Elementary school science has always been influenced by developments in the general field of education and in the society of the times. For example, the emphasis upon firsthand, sensual experience developed in Pestalozzian education led to *object teaching* as an approach to elementary school science in American schools. The need to improve agriculture, and to make rural life more attractive in the early years of the twentieth century, undoubtedly was a factor in the development of the *nature study movement.* Rapid technological changes and the tremendous developments in the physical sciences led to the extension of the range of experiences in science for children. Research into the psychology of learning and child development which showed the potentialities of children for growth and development in science extended the horizons for elementary school science.

Modern elementary school science, with its foundations in child development and its broad approach, including experiences from the physical, biological, astronomical and earth sciences, dates back only to the third decade of this century. In modern elementary school science, activities are planned to help children grow and develop in their ability to understand and interpret events that take place in their environment and within their own bodies. Often, the emphasis is on child activity, using such materials as magnifying glasses, aquariums, dry cells, magnets, motors, simple machines, thermometers, and a host of other items commonly employed in science instruction. Almost all youngsters have a deep interest in these kinds of experiences, and many classroom teachers have found that they can do some of their most effective work when dealing with the materials of science.

However, these are times of rapid change, and our programs need to be reexamined if they are to meet the needs of children who are growing and learning in present-day society.

THE NEED FOR NEW DIRECTIONS

There are four basic reasons for the reexamination of elementary school science.

1. The rapid development of knowledge in many fields of science has made it important to extend the range and modernize the content of elementary school science. Developments in science require that all science programs, including elementary school science, be revised at frequent intervals. Elementary school programs must be consistent with the findings of modern science. It has been estimated that the amount of tested scientific information that is available is being doubled every ten years.[1] Elementary school science courses of study, textbooks, and resource materials should incorporate this new information.

Some newer subsciences are not represented to the extent that they should be in our current programs. The scope of these programs should be broadened to include experiences related to such sciences as ecology, nutrition, oceanography, hydrology, meteorology, soil science, and modern physics and chemistry.

2. To develop science experiences consistent with the nature of science continues to be a need in science education. Although it is difficult to get complete agreement on descriptions of the methods used by scientists, there is general agreement that the teaching of science should be in consonance with the nature of scientific activity. Certainly, scientific activity is characterized by a willingness to consider new, pertinent information; there is also a driving search for empirical evidence, "to get the facts," and to test the validity of ideas. Such characteristics of scientific activity have been goals for elementary school science, but they have seldom been attained. One difficulty has been that the sources of information available to elementary school children have been limited. Also, it is difficult for these children and their teachers to check empirically many of the important ideas in elementary school science.

A revision of elementary school science can lead to teaching procedures that are more closely identified with scientific activities. A wide variety of excellent books, charts, and other teaching and learning materials is becoming available. At the same time, much more of the scientific equipment and apparatus that is necessary for the testing of ideas will be in schools and classrooms for use by children and teachers. The programs of the future should be designed to take advantage of such developments.

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[1] Robert Oppenheimer, "Science and Our Times," *Bulletin of the Atomic Scientists*, Vol. XII, No. 7 (September 1956), p. 237.

3. The growing importance of science and technology in our culture makes the establishment of more sophisticated elementary school science programs mandatory. Developments in science and technology have had a tremendous impact on our ways of living and on our outlook upon the world. In the past fifty years the average life expectancy has been lengthened from about fifty to about seventy years. The development of efficient internal combustion engines, making possible rapid and convenient transportation over land and through the air, has revolutionized our ways of living and reshaped our cities and countrysides. The understanding and control of electromagnetic radiation has brought the sights and sounds of distant places into our living rooms. The basic principles involved in these developments should be understood so that we can use the products of scientific enterprise wisely.

Because of the growing importance of science and technology, the youngsters of today have access to many more sources of scientific information than their predecessors of past generations. There are science programs on radio and television, attractive science books on a wide range of topics from anthropology to zoology in our homes and libraries, and science and technology are discussed more and more by people everywhere. There is some evidence that our children now "know more science." Our elementary school science programs need to be redesigned to take advantage of these new sources of information that are now available to youngsters.

4. The development of integrated K–12 science programs makes it important to examine the special contributions to be made in elementary school science. Few communities have established integrated K–12 science programs so designed that young people can build on previous experiences, avoid deadening repetition, and explore the wide range of various sciences. However, such programs are being developed, and it is essential that a unique

function for science in the elementary school be identified that is consistent and integrated with subsequent science programs in the junior and senior high schools. What kinds of science experiences can best be provided for the child in the elementary school? How should these experiences be related to the programs that are planned for junior and senior high school science? In the revision of elementary school science, questions such as these need to be considered.

THE NATURE OF ELEMENTARY SCHOOL SCIENCE

Science is the investigation and interpretation of events or phenomena that occur in our natural environment and within our own bodies. All of us, child or adult, must make some interpretation of such phenomena. In elementary school science, children learn how to make their interpretations in light of the concepts, theories and principles that have been developed in the various sciences.

Science also means investigation. Children are investigators. They are interested in "finding out." The methods that are used in the sciences to investigate events and phenomena are among the most powerful intellectual tools of man. In elementary school science, children have a chance to use some of the methods of science as they strive to "find out."

Science is everyone's business, and everyone must partake in the decisions which grow out of contemporary scientific and technological achievement. When people line up to go into the voting booth, no one asks them their IQ. No one says that a person with a doctor's degree has more right to make a decision than a person with merely a high school diploma or even no diploma at all. As people make the judgments which determine the future for all of us, they need science information, and they need the techniques of rational reasoning which are characteristic of modern science. So science must be taught to everyone. It must be a part of the curriculum of every school and of every grade.

But at the same time there is no exact body of science information which every person must have. Nor is there one and only one way in which science may be taught. In fact, teaching which would present the same material to every child in exactly the same way and at exactly the same time, far from being democratic, would be most undemocratic. Since children differ in their rates of development, abilities, and interests, science programs for the American schools, while directed toward satisfying the needs of all, must be designed to satisfy individual needs and differences. Thus, on the one hand, the elementary school science program should be planned for the entire school. At the same time, the program must be adapted so that each child can achieve optimum growth and development in science.

Fortunately, this requirement that the elementary school science programs be adjusted to the needs of individuals and classes is not as difficult to meet as it would seem at first thought. Science is one area of the curriculum in which all pupils, fast and slow, active and passive, quiet and animated, explore and study with profit. The very nature of science is such that a wide variety of experiences can be provided for children regardless of their stages of development. The child is an explorer; science gives him a chance to explore. The child is a problem solver; a science program can be built around problems which children can solve. The child is a searcher after self and after his world; a science program can be structured so that he can make rational decisions about his world. The child is a social being; a science program affords many opportunities for each child to work, at his own level, with his peers, and with the teacher on a variety of acceptable projects.

But this kind of science program is by no means casual and offhand. The success of such a program is usually proportional to the amount of planning a teacher does. Having been given an over-all school program, the teacher needs to think through how he should present that portion of the program for which he is responsible.

This planning has two distinct, yet interrelated, phases. First, the teacher must study the subject matter which he is going to present. Is he going to teach about weather phenomena? He had better know the difference between an anemometer and a barometer. He had better know an isotherm from an isobar. Second, how the science is taught is quite as important as what is taught. Our approach to teaching science must be developed in terms of what we know about each individual child. One child must be encouraged to become a more active participant. Another child should be held to greater accuracy in his statements. A third youngster needs to listen and cooperate with the group more effectively. These kinds of growth are possible if the teacher plans for them. Furthermore, since science is a way of looking at phenomena as well as the factual information about such phenomena, teachers must make provision for situations in which children have opportunities to be explorers and problem-solvers. Thus, children can be encouraged to use their imagination and to seek new approaches to old questions; they can be helped to reach conclusions based on their observations; they can develop a sense of humility and the ability to alter their conclusions in the light of new evidence; in short, they can develop scientific attitudes toward their world.

As for the curriculum itself, an over-all science program is varied and many problem areas are considered. It follows, then, that materials and concepts from most of the science disciplines will appear in the program from time to time. How problems from these areas of science will be selected depends on several factors. Of course, the interests of the children at their various stages of development necessarily will be considered. But such interests will not be the sole criterion for selection. In addition, the developmental levels of the children will serve to determine placement. So will the inherent logic of the subject matter. Meanwhile, schools and teachers must never lose sight of the fact that they have a responsibility to society. Society's needs and demands must not be disregarded. Science curricula must be built so that all these demands are met.

As in the case of social studies or language arts, science has its independent program. The over-all science offering must be organized around its own series of objectives, and with its own internal logic and structure. Science materials, *per se*, satisfy the needs of both the individual and society. Of course, there are many points at which science materials are closely related to other areas of the curriculum. Where such relationships exist, and when pupils can understand them, they should be pointed out. But the science which is taught in the elementary school must be taught as science, and it must be taught so as to realize the objectives which have been established for the science program.

There are various instructional techniques for implementing the science program. Sometimes, experts will be called on for their special information, or answers will be found in reference materials. Sometimes, children will be taken out of the classroom to see how science principles are applied in industry, agriculture, or in government agencies. Sometimes, experiments will be planned and executed, or demonstrations will be provided for the pupils so that they may see how a science principle can be used. Teachers should be free to use all the resources which surround the school and the community. At every opportunity, with every technique that he uses, the teacher sees to it that his pupils relate what they already know to what they are learning, so that the new information fits into the over-all picture of the universe that each child is building for himself.

This kind of program is an essential part of the general education of every future citizen. It starts in the elementary school and continues through each individual's school career and on into his adult life. Its function is to provide him with those ways of thinking and those attitudes toward his physical world which will help him to interpret the events that occur in his environment and in his body. The experiences a child has in such an elementary school science program will help him to take his place as a contributing and creative member of society.

SCIENCE GENERALIZATIONS AND CONCEPTS

We want children to gain some understanding of the broad generalizations or "big ideas" of science. A more or less profound knowledge of a broad generalization is of more value and greater importance than the learning of a relatively discrete fact. To observe that water placed in an open pan evaporates is not as important as to gain some understanding of the water cycle. The water cycle involves a generalization that helps to explain and relate a wide range of phenomena.

Science generalizations are broad statements that help us explain a range of events, relate these events to other phenomena, and guide us as we approach the new and unknown. Our understanding of the conservation of matter and energy is an example of a science generalization. Such a generalization is based on the cumulative experience of the scientific community. Most of our science generalizations are well grounded and tested in experience, and to modify or upset a major generalization is a notable event in the history of science. We use our concepts of these generalizations as we investigate the many phases of our natural environment.

Science concepts are our views or pictures of ourselves and the world in which we live. Concepts have been called the ultimate essence of past experience. Concepts are individual possessions, and are based on the cumulative experiences of each person. A child may say, "I can make something out of nothing." This is his concept, even though it is at variance with the scientific generalization of the conservation of matter and energy. The teacher is concerned with the developing concepts of the individual child. He is concerned that the child's concepts develop in a pattern that is consistent with the generalizations of science. A few of our children may eventually develop their concepts to the point that they can extend or modify the generalizations of science.

Concept development has long been an important objective in our work with children, and the building of pervasive generalizations is a key goal in science. Those who work with children must develop for themselves as deep an understanding as possible of the generalizations of science, which will provide direction in guiding the concept development of children.

Chapter Two

THE EFFECTIVE SCIENCE PROGRAM

In the redirection of elementary school science the primary aim should be the continued improvement of the quality of science experiences that children have. Learning in science, as in other areas of the curriculum, is an individual matter, and we must try to develop programs in which each child is stimulated to explore, to find out, and to learn. "It's what happens to children that counts."

A quality program in which children have opportunities for a wide variety of good learning experiences will have clearly stated goals that suggest directions for growth and development on the part of children, and serve as guides for teachers as they plan science experiences. The program in action has certain definable characteristics that can be observed and are significant in the evaluation of the program. The science program should be based on many preceding experiences; some of what we have learned from these experiences can provide criteria that are useful in planning. The sections that follow offer some suggested goals for instruction; desirable characteristics of programs; and a set of criteria that can be employed in developing effective elementary school science programs.

GOALS FOR ELEMENTARY SCHOOL SCIENCE

Some science educators have suggested that the greatest weakness in elementary school science as it is currently taught is the lack of clear, understandable, worthwhile goals. Seemingly, there is a plethora of activity, a concern for reading for the sake of reading and, far worse, an urge to include almost any type of science material because now everybody expects to see "some" science in the elementary school curriculum. But why include science in the curriculum? What should pupils gain from their experiences in science? What aims and goals should teachers have as they work with children in this area of the curriculum? Such nagging questions should be asked, and those who develop science programs have the responsibility to give satisfactory answers.

The general goal of elementary education may be attained by a program that will help children achieve optimum intellectual, physical, social, cultural and emotional growth and development. Since science is the investigation and interpretation of phenomena that occur in our external and internal environment, experiences in science can contribute to all these areas of growth and development. In fact, in these middle decades of the twentieth century, a lack of opportunity for satisfactory experiences in science in the elementary school will lead to stunted growth and arrested development—stunted and arrested in terms of that pathetic phrase "what might have been."

What are some important goals which teachers should attempt to achieve as they work with children in science? Many could be listed; we suggest that in any such enumeration the following five goals should be represented: (1) building a world view that is consistent with our modern scientific knowledge; (2) gaining an understanding and some skill in using the methods and techniques of science; (3) developing the ability to participate in the exciting new developments that take place in science and technology; (4) learning how to achieve optimum physical health;

and (5) preparing for participation in future policy-making on issues that involve science and technology.

Building a world view. Every individual—child or adult—has a view of the world in which he lives. This can be a narrow view that limits the individual, or it can be a broad view of man in a vast universe consistent with the world view that has been developed in the sciences. Such a world view liberates rather than limits, and it serves to open up exciting new areas for exploration.

At one time even the best educated individuals considered man to be a unique organism unrelated to other living things. This was an attitude that limited, because it prevented men from undertaking some very important studies, particularly the study of man himself.

In the modern world view, man is considered to be related to and part of the world of living things. The broad physical principles that are used to study and understand both the living and nonliving environment can also be used in the study of man. This approach has led to major advances in such sciences as physiology, anatomy, nutrition, and medicine. When children have an opportunity to develop this kind of a world view, they have a basis for studying and understanding themselves.

In the not too distant past our place of residence, the earth, was considered to be the center of a relatively small universe with all other celestial objects revolving around our all-important planet. A child with this view of the world might logically conclude that there was little in the universe outside the earth worthy of exploration.

In the modern world view, the universe is greatly expanded. There are stars and planets in a tremendous number of galaxies in a universe of vast, perhaps infinite, dimensions. The earth is one of nine planets that revolve around the sun. The sun is one of a billion or more stars that make up the Milky Way Galaxy. The Milky Way Galaxy is one of, perhaps, billions of galaxies that make up the universe. This concept of the universe represents a liberating point of view. It opens up almost unlimited possibilities for the study of matter and energy in space.

To a certain extent our actions are determined by our view of the world. In the older world view, man believed that he had status because of his uniqueness in the universe. Such a view hinders and hampers investigation and exploration. In the modern world view, man attains status through achievement—there is a vast, fascinating world to investigate. As children work with able teachers, manipulate and use the materials of science to do experiments and projects, read interesting science books and pamphlets, and explore the natural, physical environment around them, they will have a chance to build a world view that will open doors to challenging future studies.

Using the methods of science. The methods and approaches employed in the sciences to investigate and deal with problems have proven effectiveness. The application of these methods and approaches has led to profound advances in the understanding and control of our environment. Perhaps one of our most important goals is to help pupils gain some understanding of the approaches and some skill in using the methods that are employed in the sciences to deal with the questions and problems that may arise.

In a monograph such as this, we cannot describe all the approaches and methods that may be characterized as "scientific." However, we can cite some examples in which children have experiences with scientific approaches and methods in the solution of problems.

In the sciences suggested answers or proposals for action must withstand empirical, experiential tests. In other words, when observations or experiments are undertaken to test a suggested answer or proposal, does the suggested answer or proposal work? For example, various statements have been made in journals and textbooks that a deer fly can travel at speeds of more than 700 miles per hour. Although this speed would be greater than the speed of sound, the statements were accepted uncritically for a long time. When the empirical test was made, the speed of flight of the deer fly was found to be much less than the reported 700 miles per hour. Similarly, in elementary school science, pupils should have the experience of having their statements subjected to empirical tests. In one classroom, a child stated that a plant could not grow if it were turned upside down. This idea was subjected to an experiment or test. The children inverted a flower pot containing a growing plant to see if it would continue to grow when it was tipped upside down. From such experiences children learn to demand empirical tests of suggested answers and proposals.

In science an attempt is made to have the findings of one person checked by others. This is sometimes called the public dimension of science. If certain results are obtained by observation or experimentation, the methods employed in the observations or experiments must be described so that the results can be checked by other scientists.

Children also can have their observations and ideas checked by others. In connecting some flashlight bulbs to a dry cell, one youngster claimed to have felt a slight electrical shock when he scratched one end of the wire on a dry-cell terminal to get a small shower of sparks. In the class discussion, the teacher encouraged the youngster to describe exactly what he had done so that his classmates could check to see whether they received shocks when they scratched a wire on the terminal of a dry cell. In elementary school science, children learn the importance of describing their observations and experiments in such a way that their results can be verified by their classmates, teachers, and anyone else who may be concerned.

The experiment in which all variables but one are controlled is an important tool in the sciences. One group of children wanted to ascertain whether or not a cover crop such as grass was effective in preventing soil erosion. To find out, they decided to set up a controlled experiment. They were helped to think through all the factors that would have to be controlled if their experiment was to be a success. They filled two shallow boxes with soil and covered the soil in one of the boxes with grass sod. They leaned the two boxes together so that the slope of the soil in both boxes was exactly the same. They adjusted a sprinkling can above the boxes so that an equal amount of water would fall on each of them. They placed tin cans beneath the openings at the lower end of each of the boxes to catch all the water and soil that would run off. In other words, they made the conditions for each of the boxes exactly alike so that they could test the effectiveness of a grass cover in preventing soil erosion. In experiences such as these, children have an opportunity to learn how to use controlled experiments as a tool in investigations.

The foregoing are examples of some of the experiences that children can have when they are taught to employ the approaches and methods of science. A teacher who has some understanding of the methods and approaches of science can provide learning experiences which will help young people to deal more effectively with the questions and problems they will meet throughout their lives.

Participating in new developments in science and technology. During the past sixty years many developments have occurred in science and technology. During this period man made his greatest progress toward an understanding of the nature of matter and the interrelationships of matter and energy. The foundations were laid for such new sciences as biochemistry, biophysics, genetics, geophysics, and radiology. The technology in such fields as transportation, communication, agriculture, and textiles was revolutionized. The grandparents of the children in our elementary school classrooms have seen all these developments and many more occur within their lifetime. Will today's children have a similar experience?

It is likely that the near future will witness an acceleration in scientific and technological progress. This will occur, if for no other reason, because more able and well qualified people than ever before are engaged in the study of scientific and technological problems. We will gain a better understanding of the planet earth on which we live, and the various physical processes that take place within the earth. The exploration of outer space has begun, and the tempo of exploration will be increased. New sources of energy may be tapped, such as those that give off energy in the sun and other stars. It appears likely that one of the most exciting periods in human history lies ahead; a period that will be characterized by exploration, discovery and an increase in control over the natural, physical environment. Will our children have an opportunity to participate in these developments? To a certain extent this depends upon what happens in elementary school science.

In a sense, everyone can participate in the developments that take place in science and technology. Through education, everyone should be equipped with the intellectual tools to read of science with understanding, listen with comprehension, and view with appreciation. Some of the children in our elementary school classrooms will become scientists and technologists. But it is not the job of the elementary school to train these scientists and technologists. It is, however, the function of the elementary school to help everyone, regardless of his future calling, to keep informed of scientific developments and to understand the quest for better interpretations of the phenomena that occur in the natural, physical environment and within our bodies. In doing this, the door of opportunity is kept open for those young people who wish to become scientists and technologists.

In the elementary school children can develop some of the skills and understandings that will help them appreciate scientific and technological developments. They can become familiar with some of the terminology of science so that they can read, listen, and discuss with understanding. They can develop a comprehension of some of the broad generalizations of science so that they can interpret and evaluate what they see and hear. They can become aware of some of the methods used in the sciences so that they can judge the results of investigations. These are some of the ways that our children can be helped to participate in the developments of the future in science and technology. For many it will be a passive participation, but others will unquestionably play more active roles.

Learning how to take care of their bodies. Johnny comes to school in the morning having had a cup of coffee and a doughnut for breakfast. Mary may have had no breakfast at all. By late morning both Mary and Johnny become restless and fidgety, and the chances that they will be able to study and learn are practically nil. Both teacher and parents may contemplate why Mary and Johnny are so susceptible to colds and have to be absent from school so much. They are both malnourished, and they will not be able to maintain optimum health and happiness until their bodies receive the food materials they need.

If our children are to achieve optimum growth and development and have an opportunity to live happy lives, they must have a chance to learn how to take care of their bodies. Good physical health will not necessarily lead to happy, productive lives. But happiness and achievement are difficult to attain without good physical health.

In elementary school science children can learn some of the basic scientific principles which relate to good health. By using the modern knowledge of nutrition, most children can make certain that their bodies get the nutrients that are needed. Through an understanding of how various diseases are transmitted, they can protect themselves against numerous infections. By establishing resistance to disease through immunization, certain potentially fatal infections can be prevented. To learn how to lead a healthy life should be one of the most important goals of elementary school science.

Learning to be effective citizens. In a democracy each citizen has a responsibility to help solve the problems and decide the public issues that arise in the community—the international as well as the local community. Some responsibilities that fall upon the shoulders of our citizens are of considerable magnitude. And the citizens of tomorrow are in our elementary classrooms today.

In our modern scientific, technological, industrialized societies, more and more of the problems and issues to be dealt with and resolved involve science and technology. For example, the citizens of today and tomorrow will have to deal with such questions as the following: How can we protect and make the best use of such natural resources as soil, water, minerals, forests and sources of energy? How should our radio broadcast bands and television channels be utilized and controlled? What are the best ways of providing for national defense? Should there be testing of nuclear devices and how much risk should we take with radioactive fall-out? What approaches should we take to space exploration? How much time and energy should be devoted to science and mathematics in the curricula of our schools? All these questions are related in some way or other to science and technology, and require some understanding of science and technology on the part of citizens if the problems are to be resolved satisfactorily. Our children will have to deal with these kinds of problems.

In modern societies it is important to utilize the services of people who have devoted a great deal of time to the study of certain issues and problems. These are the experts who have studied carefully such questions as were raised in the previous paragraph; their knowledge and insights must be used. Citizens must learn how to use the services of experts effectively. The right questions have to be asked and the answers evaluated. One of the important goals of elementary school science should be to help children utilize the services of people who have given concentrated attention to the study of various problems and issues.

Through experiences in elementary school science children can gain some understanding of science and technology, and learn how to employ the findings of experts so that they can deal more effectively with the problems and public issues they will face. In this way they will be helped to become more effective citizens.

CHARACTERISTICS OF AN EFFECTIVE SCIENCE PROGRAM

The quest for quality and the struggle for perfection are never-ending. It is not sufficient to have science listed in the courses of study and teacher guides, nor is it enough to allot a certain amount of time for science instruction in the school day.

Courses of study, teacher guides and time allotments are important, but of perhaps greater importance is a concept of what constitutes a good elementary school science program.

What are some of the characteristics of good elementary school science programs? In what directions can we move to improve the experiences that children have in such programs? The following analysis of good science programs provides guides for program revision and for the evaluation of science instruction.

Children's actual science experiences are considered to be paramount. As in science, the basic test of the effectiveness of a plan or program is an empirical one: "Does the plan or program work?" "Do the children actually have challenging experiences in science that help them to grow in their ability to understand and interpret the phenomena that occur in their natural, physical environment and within their bodies?" In effective elementary school science programs, it is fundamental that the pupils have a variety of profound experiences that help them to question, investigate and interpret so that they will be led to grow in their understanding of science.

This empirical test of effectiveness is essential. Comprehensive plans can be promulgated; activities can be logically planned, cleverly developed, and executed with efficiency; but the critical test is what happens to the children. In effective elementary school science, pupils must be able to understand the books and pamphlets that are provided for them to read, handle the equipment and apparatus that are used, comprehend the discussions, and be cognizant of the purposes and reasons for various activities. In such programs, the actual experiences of children are paramount, and teachers and administrators are sensitive to the reactions of children as they take part in science experiences.

The classroom teacher is informed, resourceful, and enthusiastic. The classroom teacher is the key to a good program. If the teacher's approach to teaching science is dull and uninspiring, the program will certainly fail. However, if children have the precious opportunity for infectious exposure to the enthusiasm of a teacher who knows science, likes science, and enjoys working with children in science, they can have the doors opened to one of the most fascinating areas of human endeavor.

A classroom teacher must be informed in the field of science. This teacher should have taken at least two years of science courses in undergraduate college work. This basic work in science provides a foundation upon which the teacher can build continuing studies in science. The administrator who is concerned about the quality of children's experiences in science will want new teachers to have had this basic undergraduate science background.

Good elementary school science is characterized by a variety of approaches to teaching and learning, and the successful teacher must be resourceful in developing appropriate science activities. It is not enough to know the basic generalizations of science; the teacher must also provide a variety of ways that children can be helped to learn something about them. Professional courses in teaching elementary school science are designed to help teachers develop this resourcefulness. Various professional books and journals provide sources of ideas for teaching. Elementary school teachers need the professional background in elementary school science as well as the background in basic science.

Often we become enthusiastic about those things in which we have success. It has been said that the children are the best lobby for elementary school science. Once they have had some contact with science they want more. A teacher who has seen the fascinated interest that children have in science may wish to delve further into this rewarding field of work, study, and teaching.

Children's interests and concerns in science are considered and developed. The day after Sputnik I was launched into space, the children in one classroom were alive with questions and comments. "How was the earth satellite launched?" "Why doesn't it fall down?" "How long will it stay up?" The teacher allowed a few minutes at the beginning of the day for a discussion of the earth satellite and then said, "Now, we must return to our spatter painting."

This was a lost opportunity. The teacher should have worked with the interests and concerns that the children had about satellites. Since they had these concerns, it is doubtful that any other educational activities could have been of much value at that time. In a good program the children's interests in science are nurtured, and they are used as a basis for planning field trips, projects, experiments, demonstrations and a wide range of reading. In good programs some of the most fruitful activities grow out of the questions and problems raised by children.

A planned program of exploration is provided. There should be a planned program of exploration into various areas of science. Some background information and knowledge in such fields of science and technology as health, conservation, nutrition, electricity, and energy utilization are essential for the growth and development of children and the welfare of the society in which they live. Explorations by children in such fields should be carefully planned by teachers, school administrators and leaders in curriculum development.

Children should also be provided an opportunity to explore areas of science with which they have had little acquaintance. In one school, various kinds of magnets were scattered around on the classroom tables. A small group of youngsters came in and asked, "What are these?" A teacher said, "These are magnets. Let's see what we can do with them." The children and their teacher tested to find out what kinds of things were attracted to magnets, what happens when two magnets are brought near each other, and how magnets could be made. Although they did not initially recognize the objects around the room as magnets, these children became keenly interested in the study of magnetism. The planned program of science should be viewed not as subjects "to be covered" but as plans for exploration into the new and the fascinating.

Science experiences are an integral part of the total elementary school program. In the elementary school we are concerned with the growth and development of children. Many kinds of experiences can lead to growth—experiences in reading,

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arithmetic, social studies, art, music, and science. These experiences are not discrete and unconnected and should not be unnecessarily compartmentalized. Instead, the relationships between these various kinds of activities should be stressed, and the classroom teacher who works with children in all these areas is in an unusually favorable position to foster understandings of this type.

The relationship between science and reading is an example of how one kind of experience can help in the development of abilities in another field. Words and sentences are symbols for experience. Experiences with material things such as aquariums and dry cells are often especially clear and meaningful to children. Many a child has learned to read from experience charts that have been developed out of what he has observed in setting up an aquarium or experimenting with dry cells. He learns the words that signify the experiences in which he has participated. Similarly, many youngsters have improved their reading by continued use of well-written, exciting science books that help children find out what they want to know. The desire to read is enhanced when the child has books to read, such as children's science books, that he recognizes as being interesting and of value. These are a few of the manifold ways in which science can be made an integral part of the school program, and can be used to contribute to the over-all effort to provide for growth and development.

Elementary school science is an integral part of the total elementary and secondary school science program. Modern school systems have integrated K–12 science programs. In these programs, children and young people have a chance to explore the wide range of the sciences. Deadening and unnecessary repetition is guarded against. With the great variety of rich experiences available in the sciences there is no longer an excuse for situations that led one high school youngster to comment, "I've seen that experiment every year since the first grade." With careful planning, children and young people can have challenging experiences in depth rather than superficial experiences over and over again.

The elementary school science program is the key to the over-all science program, and provides the broad base on which subsequent experiences in junior and senior high school are based. In good programs emphasis is placed on activities in which children can have firsthand experience with events in the natural environment and with the things and tools of science. An attempt is made to develop an understanding of basic science generalizations; an understanding that can be refined and extended in later programs of study.

The actual handling of science materials is stressed and a number of resources are available for teaching. In the elementary school, children should have a chance to handle dry cells, wire, magnifying glasses, prisms, house plants, projectors, scientific toys and apparatus, and many of the other items of equipment and supply that should be available for science activities. Some of these materials will be used by children and teachers as the class studies various areas of science; other materials may be made available in science experiment centers in the school for use by individual children or small groups as they undertake projects or special studies.

A wide variety of resource materials in science—children's science books, textbooks, motion picture films, filmstrips, slides, and television and radio programs should also be available. A good school library is as essential for science as it is for all other areas of knowledge. Also, school procedures should be sufficiently flexible so that parents, businessmen, scientists, and technicians can be invited to participate when their information, skills, and insights can contribute to the program.

Consultant help in science is available to the teacher. The general classroom teacher cannot be expected to be well informed in all areas of science and acquainted with the many different techniques and materials of science. A science consultant is better prepared to meet such requirements. There should be some means whereby information pertaining to new developments in science and technology is made available to teachers and children. One of the functions of the science consultant should be to keep informed about new developments in science and technology, and supply this information to teachers and their classes. These are only two of the many responsibilities of the science consultant. In many ways the consultant is in a position to assure that the science program is dynamic and effective.

There is an in-service program devoted to science teaching. In this day and age a general education in science and some professional work in elementary school science should be considered prerequisite to teaching in the elementary school. Moreover, teachers and administrators cannot afford to remain static. There should be a definite plan for an in-service program in science. This may take the form of periodic workshops, institutes, evaluations and consultations. Through such experiences, teachers, consultants and administrators are better able to keep abreast of developments in elementary school science.

CRITERIA FOR THE PLANNING OF SCIENCE PROGRAMS

The planning for effective elementary school science programs can best be done by teachers, consultants and administrators in the local school system. In study groups and workshops, they can analyze the needs of the children in their community and region and the unique resources for study and teaching that are available, and then plan the science programs that are most appropriate. These teachers, consultants and administrators have the responsibility for putting the program into action, and will be instrumental in its success or failure. They are more likely to succeed if they know what has been planned, understand the reasons for it, and agree on the steps that should be taken for implementation.

Obviously the programs should be of the highest possible quality. A pooling of ignorance can hardly lead to perfection. To achieve quality, study groups and curriculum committees should take into consideration some of the criteria that have been tested in the experiences of other groups and have been found to be guides to the development of effective programs.

The sample program described in Chapter 3 has been developed through the use of the following criteria:

1. The program should be consistent with the developmental characteristics of children. Different activities can usually be planned for twelve-year-old pupils than those developed for six-year-olds. A good elementary school science program must be consistent with our tested knowledge concerning child development.
2. The experiences planned should nurture children's natural curiosity or desire to "find out." Many opportunities should be provided for analyzing and studying the questions and problems that they raise.
3. The activities should be planned so that children have many opportunities for direct experience with materials in their environment. They should have chances to handle the apparatus, materials, equipment and tools of science.
4. The science program should be an integral part of the school's K–12 program. The elementary school science program should be regarded as a base for the total school science program.
5. All major areas of modern science should be dealt with in the K–12 science program. Modern developments in various areas of science should be included, and the newer areas of science should not be overlooked. The physical, biological and earth sciences should be represented in each year of the elementary school science program.
6. Needless repetition of learning experiences should be avoided. If the same general area of science is dealt with more than once, there should be a different approach to it each time, and an attempt should be made to develop more refined concepts.
7. The areas of science should be developed in depth. The major limitation will be the previous experience and maturity of the pupils. Each of the areas should be developed to such an extent that children can gain some understanding of how questions and problems in that area of science can be explored and studied.
8. The activities in science should be planned so that pupils

have opportunities to use and practice some of the methods and procedures that are characteristic of science.

9. The learning experiences should be developed so that children learn to use some of the broad, pervasive generalizations of science to interpret events and phenomena in their environment and within their bodies.

10. Those who are to implement a science program must have opportunities to gain a clear understanding of the program, and should be involved in the actual planning of the program.

PLANNING THE SCIENCE PROGRAM

We have noted that the science program should be planned in the local community by the teachers and administrators who are to put the plan into action. This group should call upon all the resources and expert help that can be mustered. To some it may seem that the approaches to curriculum planning that are used in some other countries are more efficient. Small groups of experts develop beautiful plans whose internal logic is quickly recognized by other experts. The plans are promulgated nationwide by a central ministry of education. Often, however, nothing happens in the classrooms of the cities and towns. The teachers have not been involved in the planning, are unaware of the rationale of the plan, and do not understand the implications of the plan for their work in the classroom. *An elementary school science program should be judged not by its internal logic, but by how it works as teachers attempt to put it into action.*

Planning by local teachers and administrators is a way of utilizing the practical experiences of teachers in building the best possible program for the children in the local community. As they work with their pupils, teachers identify the kinds of learning experiences that are most effective. This effectiveness will vary with the locality. For example, the study of plants and animals will have to be approached differently in rural communities where children may have had a great deal of experience with farm animals and various farm crops than in urban areas where children may have had limited experiences with plants and animals. City children, on the other hand, may have more sources of science information—such as libraries, museums, and television programs—accessible to them. The local teachers and administrators usually know best how to utilize the specific educational opportunities of their communities.

Organizing to develop a science program. The exact organization that is best suited to a given school or community, and through which a vital elementary school science program can be developed will vary from one locale to the next. But there are several types of organization that have been employed with reasonable success. Of course, in small schools, it is best for all the elementary school teachers to be involved in the planning and implementation of the science curriculum. Even better than merely involving the elementary school teachers is having them work along with the junior high school and senior high school science teachers to build a unified kindergarten through twelfth grade science program for the school as a whole. Where there are far too many teachers for all of them to work on the science curriculum committee, other patterns of organization are necessary.

One of the common ways of organizing is to have representatives from different classes and from different schools in the system plan the program. These representative teachers—perhaps ten or a dozen of them—work together to plan the curriculum and the science activities for the entire system. Under the leadership of the science coordinator or consultant, such a group often will prepare a written curriculum guide to be used by the teachers in all the schools.

A representative committee such as this has many advantages. For one thing, such a committee is small, and often can operate efficiently. In a large, urban system, trying to work with several hundred teachers is likely to be impossible. At least, when a representative committee is chosen, the finished curriculum guide can be established as the *modus operandi* for the total system. In theory a certain common body of knowledge will be made available to the children in all the elementary schools.

However, one of the disadvantages of such a committee-planned program is that, although the teachers who are on the committee work long and often effectively, the teachers who are not on the committee may not know how to use the programs that have been prepared. Often there is a fear of teaching science, and many elementary school teachers "dodge the issue." The teachers who have not been involved in developing the program may take the "easy way out"—they either avoid teaching it, or teach it by rote and in a routine manner. One of the major contributions of an in-service education program is to help teachers understand and use the science programs and materials that have been developed.

In another pattern of organization, a science consultant or specialist takes the leadership, and concentrates his efforts in one school of a system until that school has an operating science program that functions in all grades. Once the program has been well established in that school, he moves on to a second and then a third building. This procedure also has inherent advantages and disadvantages. Obviously, a major problem is that unless the curriculum is arbitrarily dictated, each school is likely to evolve a unique program, and coordination of such programs is difficult. Furthermore, some schools may have to go for a considerable time without effective leadership. On the other hand, when a science coordinator or science consultant can devote most of his energy to the development of a program in one building, he can develop a truly effective program and help most, if not all, of the teachers to provide quality instruction. Once they have had the experience of success in science teaching, they are more likely to continue to work with enthusiasm.

Various combinations of these two patterns of organization can be used. Representatives from each of several schools (or grades) can form a basic curriculum committee. This group plans and proposes a tentative program for the system. Then the science consultant, working in one school after another, can help the teachers implement the plan, and even modify the plan in the light of experience. The modifications and suggestions are then returned to the original committee for review and consideration.

There are, of course, other administrative patterns for curriculum development. But certain key organizational principles are essential for successful curriculum committee structures, as follows:

1. It is desirable to have a single, responsible coordinator in charge of the total program planning, *and* in charge of the concomitant in-service science education program.
2. Such a coordinator should be well acquainted with elementary school science practices, and he should know how to work with elementary school children and their teachers.
3. If teachers are expected to carry out a science program in their classrooms, they should be involved in as many phases of its development as possible.
4. There should be a science coordinator or science consultant available to assist the individual teachers. The classroom teacher and science consultant should work together as a teaching team to develop the best possible science experiences for the pupils.

It is well to remember that development of an elementary school science program is a continuous and long-range project, and that simply instituting it by fiat in a school system will not guarantee its survival or effectiveness. Also, there should be a continuous attempt to revise the program. We should never forget that new knowledge and changing times alter the demands that are placed upon school programs.

The use of experts and resources. It is essential that the latest and most reliable information in science, new and tested ideas in science education, and the results of experiences in other communities, states, and nations be made available to those who are planning an elementary school science program. The pooling of ignorance is of little avail, nor is there much value in more or less copying materials produced elsewhere. To produce effective new programs, ways must be found to bring information and ideas to the attention of those who are doing the planning.

New developments in science, in fact whole new subsciences, must be taken into account in planning elementary school science programs. One of the best ways of doing this is to enlist the help of scientists in the local community who are working in these areas. These scientists often can explain the most significant new developments that are taking place; these are also probably the developments that are important in the communities in which the children live. In addition, basic textbooks, reference books, journals and various kinds of curricular materials should be provided for the curriculum planning committee.

New information and basic ideas in science education should also be made available to those who are developing elementary school science programs. One of the important developments in science education is the growing recognition of the need for integrated K–12 science programs in which elementary school science is the foundation. New science materials and equipment are being developed. There is an ever-increasing supply of science textbooks and trade books being produced, as well as new audio-visual materials. Various approaches to teaching are also being tried out. Many elementary school science planning committees obtain the services of specialists in the field of science education as consultants who advise them with regard to new developments of this type.

This monograph may be viewed as an attempt to present new ideas and information in the field of science education to those who are planning elementary school science programs. It is hoped that the ideas and suggestions presented will be helpful to those who strive to go beyond the usual and the prosaic in order to develop the best possible science instruction.

Chapter Three

AN ELEMENTARY SCHOOL SCIENCE PROGRAM

Science education is a lifetime affair. The child begins very early in life to develop basic concepts concerning himself and the world in which he lives. In school, from kindergarten through the university, he has opportunities for the more formal study of science. Through books, journals, newspapers and other communication media he has daily opportunities to continue to learn. In many occupations and professions he is under compulsion to pursue the study of science in order to keep himself abreast of his field.

Elementary school science is foundational to an integrated K–12 science program, and it should provide each individual with the best possible opportunity to investigate and interpret the world in which he lives. Thus, an elementary science program must meet the criteria for the planning of elementary science programs that were listed in Chapter 2. (See page 25.)

To meet the needs of children in this rapidly changing world; to develop the understandings that are necessary for them to become effective citizens and build a consistent world view; and to provide some skill in using the methods of science, *a two-dimensional* elementary school science program is proposed. The two dimensions that are suggested are the *flexible dimension* and the *planned dimension.*

THE GENERAL PLAN

A two-dimensional program. Careful planning is essential to good education. Schools are a big business, and they cannot be run on a haphazard and makeshift basis. Materials, equipment and books need to be purchased, and teachers, consultants and administrators must plan their work. In our schools the incidental often becomes the accidental, and sometimes disappears as the nonexistent. If children are to have the experiences in science that they deserve and need, there must be careful planning for science instruction.

The planned dimension of the science program provides opportunities to explore various areas of science. Very often these areas are explored in some depth, with attention to the methods of investigation that are commonly used in developing them. Children's questions, and problems related to the science area being studied are considered. The phases of science that are planned for in any particular year represent a segment of the K–12 science program, and the plans are coordinated with the plans for other curriculum areas such as arithmetic, social studies, and reading. The planned dimension serves as a guide in the purchase of equipment and books, the utilization of the resources of museums and other educational agencies, and directs the teacher in his own professional preparation. The planned dimension provides the framework for the total program.

However, there is a need for a flexible dimension in our planning for elementary school science. After all, learning is an individual matter, and we judge our programs by how much the individual child learns. In elementary school science programs there should be sufficient flexibility so that the interesting and challenging questions and problems that are raised can be discussed, investigated, and studied.

The flexible dimension of the elementary school science program is built around timely questions and concerns. We educate children in terms of where they are, rather than in terms of where we wish that they might be. Their questions and concerns, often discerning, provocative, and far-ranging, indicate "where children are." As teachers deal with these questions, they have many opportunities to demonstrate scientific approaches to problem-solving. There are "teachable moments," and in the flexible dimension the alert, resourceful teacher makes the most of these opportunities. The rewards may be seen in the intellectual growth of children.

Obviously, there are many interrelationships between the two dimensions of the elementary school science program. The questions that children raise may indicate the areas of study that should be included in the planned dimension of the program. Certainly these questions suggest the interests that children have at the moment. Their responses to questions and their skill in undertaking various science activities indicate their strengths and weaknesses in science. Similarly, planned science experiences may open up various areas of special interest to a child or a group of children. For example, as a result of a planned study of animals, a small group of youngsters undertook to make a survey of the kinds of birds that could be found in their community. When such interests are aroused by the planned science activities, opportunities should be provided to pursue these interests. With imagination and ingenuity the resourceful teacher can use the planned and flexible dimensions of the science program to provide dynamic learning experiences.

THE FLEXIBLE DIMENSION OF THE PROGRAM

In the flexible dimension of the elementary school science program, we are primarily concerned with the interests and needs of children as expressed through their questions and concerns. Since the purpose of the elementary school is to help children achieve optimum intellectual and physical growth and development, this phase of the science program will almost always be closely related to work in other areas of the curriculum. Excellent science experiences are often developed as part of a broader study. The flexible dimension also makes it possible to meet the wide range of individual differences in ability and interest to be found in most elementary schools.

The development of experiences in the flexible dimension of the program is difficult because there are no patterns that can be laid down and followed; there are only guidelines which are suggestive rather than prescriptive. This phase of elementary school science tests the imagination, ingenuity, resourcefulness and the background of experience of the teacher and the science consultant. The potential results, however, are well worth the investment in effort and risk of one's sense of security that are inevitably associated with a venture into realms where the answers are not already known and there may even be doubt as to the procedures that should be used to deal with the questions and problems that are raised.

Since no definite pattern for the flexible dimension of elementary school science can be laid down—for then it would no longer be flexible—we would like to suggest some possible approaches to this aspect of science education and give some illustrations of how these approaches have been used in elementary schools. We hope these illustrations will be suggestive of many other ways in which such science experiences can originate.

Developing science experiences from children's questions. Almost all children raise a wide variety of questions related to science. These questions may range from "What kind of a tree is that on the playground?" to "What holds matter together?" Some questions are obviously superficial, while others are penetrating and profound. In some questions the pupil's interest is transitory, but in others the drive "to find out" may be great enough to sustain prolonged investigation. With knowledgeable guidance from teachers who are aware of the significance of various questions and what these questions may indicate about a child's development, items can be selected that will serve as springboards for fruitful study.

Through the investigation of the questions they ask, children can enhance their skills for dealing with problems. Many of these skills are similar to those used in scientific investigations. Children can be helped to clarify the exact meaning of the questions they ask. They can learn to formulate hypotheses that serve as effective tools in their investigations. They can learn how to search for and evaluate pertinent information.

In one classroom the teacher encouraged the pupils to raise questions for which they wished to find answers. Those children who asked the same or similar questions worked together, with the help and guidance of the teacher and science consultant. When the investigations were completed, the results were reported to the entire class which served as a kind of "research" seminar to evaluate and criticize the reports.

One group studied the problem, "Is there life on other planets?" In the process of clarifying this problem, they quickly found that they would have to find answers to two questions: (1) "What conditions are necessary for life?" (2) "What are conditions like on the other planets?" In the classroom and library they studied these two questions. They examined the plants and animals they had in their classroom to determine what they needed in order to live. In the library they checked their results with those given in trade books and textbooks. They obtained descriptions, based on the best available scientific evidence, of conditions on the other planets. They also checked further to see if there were living things that could survive under such conditions. They evaluated their findings, prepared a report, and presented it to their class.

When this group reported, a number of challenging questions were asked that forced them to reexamine their answers and the procedures they had used in obtaining them. For example, in their report they made the statement that Mars is the second smallest planet in the solar system. One of the boys in the class challenged this. He said that Mars must be the third smallest planet because both Mercury and Pluto were smaller. The children, however, had checked this and found that the latest information to which they had access (judging by the copyright date of the book) stated that the size of the planet Pluto was not definitely known and that it might be larger than Mars.

These children learned how to find answers for themselves, using procedures *similar* to those used in research. They discovered some things about checking and evaluating information and sources of information. Needless, to say, they also learned a great deal about the conditions necessary for life, and about the other planets in the solar system.

Developing science experiences as a part of a broad area of study. Elementary school pupils often engage in the study of broad areas which encompass materials drawn from many subject fields. Thus, they may study some region of the world, such as Africa or Latin America; a national or international organization, such as the United Nations; or what happens to a person as he grows up. Obviously, materials, information, and ideas from various sciences will contribute to the study of all these topics.

In broad-area studies, children may learn the functional relationships among various branches of knowledge. We are often told that science should not be studied "in a vacuum." Instead, the relationships among science and other disciplines should be stressed. In the study of these broad areas pupils also have a chance to learn how the methods and generalizations of science can be applied to the solution of human problems. They may also become aware of some of the problems that have arisen as a result of developments in science and technology.

One class became engaged in a study of the city and region in which the pupils lived. They learned about its history, geography, economics, some social problems, and plans for the future of the region. An important phase of their activities was the study of the natural resources available to the people in the region. This city had once been an important seaport. The pupils read about the characteristics of a good harbor, and tried to find out why their port had ceased to be important. Among other things, they found that the water in a harbor should be deep enough to accommodate large ships. In their port the water was deep enough at only certain times of the day, while at other times ships were actually grounded in the mud. As a result of this observation they made a further study of the tides in the harbor, and tried to find a relationship between the periods of especially high and low tides and the phases of the moon.

In the past, the principal source of energy in the same city had been coal. Now, a nuclear power plant was being constructed on the banks of a nearby river to the great concern of the coal-mining industry. The children learned how both nuclear energy and coal can be used to generate electricity. They also studied how electrical energy is transmitted, and tried to find out relative costs of generating electricity from nuclear energy and from coal.

These children had a chance to use science to get a better picture of the city and region in which they lived. They gained some understanding of problems that have arisen as a result of developments in science and technology. Certainly, studies of this nature will help pupils to become better citizens.

Developing science experiences related to other subjects. There are interrelationships between science and almost all other areas of the elementary school curriculum. Almost every problem that exists for men in today's world—certainly every social problem and probably most personal problems—are interwoven with considerations that relate to science and the scientific enterprise. Many excellent science experiences can be developed in the process of studying these other areas of the elementary school curriculum.

There must, of course, be careful planning for science experiences related to the work children are doing in other curriculum areas. It is not enough merely to mention the science aspects of some area. Instead, carefully planned units of study should be developed. For example, if a sixth-grade class is studying the United Nations, the teacher and children may plan a unit on the natural resources of the world. Certain simple tests and experiments with raw materials and finished products may be carried out. Field trips may be taken to farms, factories, mines and other production centers. In this way children have an excellent opportunity to learn of the science and technology involved in obtaining and processing raw materials, and in the manufacturing of the finished products needed by people. Obviously, these are important science experiences.

Significant instruction in other areas of the curriculum such as arithmetic, reading, and social studies can also be developed out of the work in science. The study of foods and nutrition can very well lead into a study of proportions and weights, the handling of money, family budgets, and the study of world food problems. The teacher who guides children into these areas of study will help them to see the important interrelationships between science, social studies, arithmetic, home economics, and art, and certainly these are important understandings for the learners to achieve.

Science experiences to meet individual differences. One of the most important considerations in the flexible dimension of the elementary school science program is to provide experiences that are of optimum value to children having a wide range of interests and abilities. Since our aim is to help each child achieve optimum growth and development, we must take cognizance of differences among pupils, and plan programs that meet the needs of all, whether they are slow learners or rapid learners and whether they seem to have little interest in science or are highly motivated.

The key to developing science experiences to meet individual differences is to know each child well. As soon as possible the teacher and others who work with the pupils should know something about the background of each individual. They should learn how to relate new experiences to the past experiences of each child. An able teacher will use this knowledge as a guide in carrying on class work. The teacher will call on this child for one kind of participation, and another child for some other kind of response. The teacher should begin to get a picture of the varied interests, and become aware of the range of abilities in his class. The imaginative teacher is more interested in potentialities than in limitations. This teacher deals in futures, and has the opportunity to increase the potential of each of the children in the class group.

Some kinds of science experiences are essential for all young people. Experiences related to food, nutrition, health, sanitation, weather, and climate are important to all individuals rather than only those who are "science oriented." All people need some familiarity with such areas of knowledge, and there is much to be said for having all children work together in learning about them. However, some children will study and understand only the bare essentials in these areas. Other children should be encouraged to delve as deeply as they can. A variety of opportunities to study and to learn must be provided if we are to meet the needs of all.

One of the approaches in dealing with individual differences is to encourage children to undertake personal or small group investigations or projects. A group of highly motivated youngsters, for example, made a study of the moon that would have been a credit to students much older than they were. Among other things, they built a telescope with which they could make a detailed study of the moon and prepared a rather sophisticated map of this satellite. In some cases science fair projects also are fine examples of what young children can do. Some youngsters have even undertaken minor research investigations. The results of their efforts may be reported to a class, a science club, or they may "publish" their paper in a "science journal" produced by the school. The foregoing examples represent ways that children who have a special interest in science may be motivated to delve deeper into areas which have special challenge for them.

Special periods during the school week may be set aside for science investigations and work on projects. When pupils are really interested, this kind of work will be continued after school and on week ends. For these activities, groups of children of various ages can meet together. Younger and older children have a chance to work cooperatively on projects that are of mutual interest.

The consultant can use his knowledge of science and elementary school science activities and materials to suggest projects and questions for investigation, and help pupils in the use of science equipment, materials and apparatus. Science-motivated youngsters can ask questions and require assistance that will tax even the resources of people with good subject-matter backgrounds. Such youngsters deserve the best guidance and assistance that can be provided them; for their sake and ours it is essential that they receive it. One of the most important contributions of the elementary school science consultant is to work with these children and help them progress as far as may be possible.

THE PLANNED DIMENSION OF THE PROGRAM

Through the planned dimension of the elementary school science program children encounter a wide range of experiences, and are assured of some contact with the major areas of science. Given a well-planned science program, young people can investigate the phenomena of their environment, gain a better understanding of themselves and how they grow, begin to learn the meaning of some of the major scientific generalizations, and become acquainted with some of the methods that are used in the sciences. Good planning will assure that learning is cumulative; the pupils build on their past experiences to gain deeper and more accurate understandings.

The experiences that are suggested in the planned dimension of the elementary school science program are drawn from six broad areas of science:

1. THE EARTH ON WHICH WE LIVE
2. HEALTHFUL LIVING THROUGH SCIENCE
3. THE EARTH IN SPACE

4. Machines, Materials, and Energy
5. The Physical Environment
6. The Biological Environment

These are the major areas of science and technology in which children should have experiences in the elementary school.

In developing the planned dimension of the elementary school science program, the criteria listed in Chapter 2 served as guides. For example, all major areas of modern science are represented in the program, and some of the units are designed to emphasize modern developments in these areas. Needless and deadening repetition is avoided as various areas of science are developed in greater depth than in preceding science programs. This planned program of elementary school science is articulated with the K–12 science program developed by the Science Manpower Project.

The science units suggested for each grade level are designed to be consistent with the developmental characteristics of children of that age. Work with the *concrete materials* of science are stressed in the units for young children. While continuing to use concrete materials, older pupils are led to consider more abstract ideas. For example, young children study rocks, and learn to answer such questions as: Why is this rock smooth and round? How many different kinds of rocks can we find around here? Do the little rocks around here look like the big ones? The older children study the history of the earth, but in order to study this history, they first must know about the rocks to be found in their community. The older children will need to review what they already have learned about rocks. Then they will go on to make more detailed studies. (What gives these rocks their distinctive colors? Why are some of them soft while others are very hard?) They will also want to learn about the ways in which modern scientists have put all this information together to derive their hypotheses about the origin and history of the earth.

In each of the broad areas of elementary school science children should learn to understand and use some of the important generalizations that have been developed in that phase of science. In the discussion of the six broad areas of science that follows, some of these important generalizations are stated. In addition, key questions related to each area are listed. These key questions indicate approaches to the study of each area. The generalizations suggest the directions in which we want children to develop in their study of science. When they have acquired a functional understanding of these generalizations, they will be well on their way to a much more profound understanding.

The general scheme for elementary science instruction recommended herein is shown in the table on page 43. This table will serve as an introduction or overview of the program. More extended discussion of each unit proposed will be found elsewhere.

SCIENCE IN THE KINDERGARTEN

In the kindergarten[1] the work in science is often a part of the total of experiences that teachers plan to attain the goals of kindergarten education. Chief among these goals is the aim of developing desirable social behavior. Through their work with science, children acquire a fund of knowledge useful for interpreting the environment and operating successfully in it, and develop initial skills in problem-solving and such attitudes as open-mindedness and critical-mindedness. All these acquisitions contribute to the broad goal of establishing desirable social behavior.

The planning of successful kindergarten science programs is guided partly by the evolving interests of the children, and partly by the teacher's view of the needs of the children. The children's interests are many and far-ranging. In fact, it has been found that the interests that children express will generally involve all six major areas of elementary school science. The teacher's view of

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[1] Many of the suggestions for the kindergarten science program have been supplied by Dr. Louis T. Cox, Jr. For further suggestions on science in the kindergarten, see his study, *Working with Kindergarten Children in Science.* (Baltimore, Maryland: State Teachers College at Towson, 1959).

The Planned Dimension of the Elementary School Science Program *

Broad Areas	Kindergarten	Grade I	Grade II	Grade III	Grade IV	Grade V	Grade VI
The Earth on Which We Live *(Page 49)*	A variety of science experiences from all broad areas of science *(Page 42)*	Study of Rocks	Study of Soil	Weather and Climate	The Earth's Changing Surface	History of the Earth	The Earth's Resources
Healthful Living Through Science *(Page 70)*		Foods We Should Eat	Preventing the Spread of Disease	Our Ears and Hearing	Our Eyes and Sight	Good Nutrition	Community Sanitation and Health
The Earth in Space *(Page 85)*		The Earth and the Sun	Air and the Atmosphere	The Sun and the Planets	Oceans and the Hydrosphere	Space Exploration	The Milky Way and Beyond
Machines, Materials and Energy *(Page 103)*		Simple Machines	Heat and Temperature	Energy and Energy Sources	Water and Water Supply	Simple Electronics	Flight in Air and in Space
The Physical Environment *(Page 115)*		Study of Magnets	Fire and Fire Protection	Sound and Music	Light and Photography	Electricity	The Materials of Our Environment
The Biological Environment *(Page 126)*		Animal Life	Plant Life	Living Things and Their Environment	Organization of Living Things	Adaptations of Living Things	Man's Use of Living Things

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* We believe that the planned dimension of the *Elementary School Science Program* is consistent with criteria listed on pp. 29–30. Obviously, there is nothing sacrosanct about this organization and grade placement, and a school system can modify this planned program to meet needs that may be unique in its community.

the children's needs will evolve out of continuing study of the children.

Many of the more significant science experiences in the kindergarten have their origins in questions that children ask, and give rise to the following kinds of activities:

1. Formulating specific questions
2. Planning ways to find information
3. Finding information by consulting books, pictures, films, and people, and by taking part in experiments and excursions
4. Suggesting and testing tentative answers
5. Summarizing and using the findings

These activities can, of course, contribute greatly to the development of problem-solving skills.

The flexible dimension of science instruction is likely to be far more significant than the planned dimension. Kindergarten teachers must be continually aware of possible interests and be ready to exploit them; at the same time, they must be careful not to overextend them. On the other hand, a science program that is based on incidental experiences alone may soon be based on accidental experiences and eventually become nonexistent.

Clearly, there are two things which the kindergarten teacher must do. First, she must examine her regular program of activities, and from the varied experiences which her children have had, she must choose those which have science implications. She can exploit these implications in her instruction. For example, a common part of the kindergarten experience is block play, which relates to science concepts of size, weight, and balance. Another common experience involves the use of water in various activities. Here again the teacher can direct attention to science concepts: water as a liquid, water as snow, water as ice, and possibly even water as steam. Such science experiences relate directly to the regular kindergarten program.

In the second place the kindergarten teacher must plan to introduce several (perhaps five or six in the course of the school year) planned experiences from the area of the sciences, just as she will introduce new experiences in the areas of the arts and language. Choosing the kinds of science experiences to employ requires the same kinds of criteria that serve to select appropriate kindergarten experiences in other curricular areas:

1. Can the learners have a variety of sensory experiences relating to the concept proposed for study?
2. Can the learners isolate the concept from other factors in the environment, and thus be able to concentrate upon it?
3. Can the learners see applications of the concept in their own lives? Can they see applications in their classroom and home experiences?

If the teacher examines concepts in the light of these criteria, she will be able to choose those that are appropriate for her particular group. However, one caution must be noted: These topics should only be developed to the extent that the children are able to understand them. We should not try to make science specialists out of five-year-olds.

It is suggested that kindergarten children have a wide variety of science experiences, often of short duration, dealing with many aspects of science. They may, for example, profitably have experiences with plants, animals, weather, and heat within a relatively short period of time. A kindergartner should have the freedom to move quickly into an area of interest, work intensively for a short time, and then move on to new interests. Children will return many times to such topics as plants, animals, weather, and energy. To an observer such a program may initially appear to be fragmentary and disorganized. To the children and teacher, however, the coherence and unity of the program will appear obvious.

Some activities should be carried on over a considerable period of time. Examples are keeping a daily record of the weather, feeding and caring for animals, studying the growth of a plant, and keeping a book of drawings based on science experiences. Such activities help children to learn how to interpret observations made over an extended interval, develop a sense of responsibility for the wise use of materials in their environment, and provide for a continuity among experiences throughout much of a school year.

A variety of kindergarten science experiences can be planned that will help children to become better acquainted with their natural environment and the materials of science. The science experiences often become the vehicle for teaching language and number skills. Of course, the teacher takes the leadership in these experiences, but the children should participate actively and have a chance to handle science materials. The examples of specific kindergarten science experiences suggested here are commonly employed in kindergarten programs:

Collecting and finding out about leaves: colors, shapes, names, differences.
Making a "leaf tree" of paraffin-dipped leaves.
Making spatter prints, blueprints, and plaster casts of paraffin-dipped leaves.
Collecting and finding out about seeds, flowers, fruits, and nuts.
Displaying seeds in plastic or cellophane envelopes.
Planting seeds in paper cups, bowls, or flower pots; studying how plants grow.
Cutting open seeds; using a magnifying glass to see parts.
Sprouting bean, radish, or grass seeds on moist blotter between glass plates, or on moist sponges.
Finding and studying various kinds of soil for the growing of plants.
Observing and studying animals: including birds, insects, turtles, snakes, squirrels, frogs, and salamanders.
Establishing a bird-feeding station on a window sill, in a tree, or on the ground; studying the food habits of birds.
Keeping a praying mantis and observing egg-laying; or keeping a caterpillar and observing cocoon-spinning; or finding cocoons and egg cases from which adult insects may emerge in the warm classroom.
Experimenting to find out about burning: putting out candles by using a snuffer, sand, water, or blowing; comparing candles burning under large and small jars.

Saving pumpkin seeds, finding good soil, and planting the seeds.

Following children's interests may involve studies to find out more about light, shadows, transparency, color, the sun, and day and night.

Cloth, spinning, and fibers.

Transportation, wheels, friction, and the study of some simple machines.

Finding out about furs and meats as animal products.

Discussing good dietary habits.

Taking excursions to see trees and how they grow: needles, cones, and seeds.

Discussing the importance of trees: conservation.

Finding out about lights and toys: electricity.

Experimenting to find out how electricity is used to produce light, and to make things go: cutting open a dry cell; using wires and dry cells to make bulbs light; making electrical toys run; opening a flashlight; making a bell ring.

Installing an electric bell in the playhouse.

Discussing safety with electricity: dry cells are safe to touch, but house electric outlets are not.

Finding out about mechanical toys.

Building various kinds of machines with building sets; studying stability and balance with blocks.

Finding out how wheels are used; why machines are useful; how various kinds of energy are used through the study of their toys.

Learning about inertia, balance, and safety around machines.

Finding out about sanitary practices and the reasons for them: in the lavatory, in the cafeteria, at the fountain, at snack time, and when coughing or blowing nose.

Participating in a planting project on the school grounds.

Finding out how electricity, heat, light, and air are brought into the room.

Finding out about the fire department: seeing the tools and protective clothing firemen use; examining a soda-acid fire extinguisher; seeing a soda-acid or carbon dioxide extinguisher used; discussing fire hazards and safety; seeing soda and vinegar react; putting out a match or candle flame with sand and water.

Finding out how water comes to our homes: experimenting with hoses or rubber tubing and funnels to see how water goes through pipes; filtering muddy water through sand; using maps to find the reservoir and other parts of the supply system.

Visiting a dairy, a building project, a farm, the harbor, the railroad station, a store, and a manufacturing plant to find the answers to children's questions.

Using a world globe and toy figures to explain the meanings of up, down, gravity, the shape of the world, space, and sky.

Using a spotlight and globe to answer questions about day and night.

Discussing questions about sky and space.

Using flat maps and a sandbox to develop ideas about land forms.

Collecting rocks and earth products: finding out about some of the earth's resources, including names, uses, and the need for conserving them.

Hatching eggs in the classroom, using an electric light in a box incubator; making a pen and caring for chicks.

Collecting and finding out about flowers: arranging flowers in vases; forcing forsythia and pussy willows to blossom.

Finding suitable soil, and planting seeds of flowers to be transplanted outside later: use paper cups, flat boxes lined with waxed paper or metal foil, or flower pots.

Finding out about growing plants by making bowl gardens (e.g., carrot and beet tops, ivy cuttings, white-potato eyes) in shallow water.

Growing a sweet potato vine in a culture bowl.

Sprouting seeds of corn, beans, radishes, lettuce, grass, etc., between the sides of a glass tumbler and a damp blotter or sponge.

Collecting and preparing to care for frog eggs or tadpoles, butterfly or moth eggs, cocoons, and animals from the stream or woods such as snails, salamanders, slugs, insects, frogs, and turtles.

THE EARTH ON WHICH WE LIVE

In this broad area of science, young people study many of the important features of the solid earth, and the changes that take place in the atmosphere surrounding the earth. The study may involve the schoolyard, empty lots, fields, beaches, lakes and ponds, hills and valleys, roadcuts and parks in the immediate neighborhood. Later, features of the earth around the world can be studied, and children can begin to gain an understanding of the various processes at work in the earth and in the atmosphere that surrounds it.

One of the basic understandings that pupils should gain is that the phenomena they observe in the atmosphere and on the surface of the earth can be explained through the use of general physical principles. In fact, a basic assumption of the science of geology is that these physical principles have been in operation since the universe began, and we can explain what happened in the past by using these physical principles. For example, the kind of material that settles to the bottom of a lake or ocean depends upon the kind of material that is washed into the lake or ocean by rivers and streams. In the summer when the rivers are slow and sluggish only very small particles are carried into the sea or lake. In the spring or fall when the rivers and streams flow more swiftly, larger particles will be transported by the swollen streams. If a child finds a rock containing alternate layers of small and large particles, the rock was probably formed from particles deposited during different seasons of the year long ago. In other words, we are assuming that soil particles were carried by rivers and streams in the same way in the past as they are today. The assumption that general physical principles can be used to explain the phenomena that we see provides us with a powerful tool for the study of the earth on which we live.

Other approaches to explaining the phenomena of our environment have been used in past times. For example, such features of the earth's surface as mountains and folded layers of rock have sometimes been explained as the results of sudden catastrophes. Older children may consider various past and present theories about features of the earth's surface. They can be encouraged to examine each of the theories critically. From this experience they should gain some understanding of man's effort through the ages to understand his environment, and this is an important accomplishment for elementary school pupils.

Many of the phenomena that occur on the earth and in the atmosphere are parts of broader cycles. The rain that falls on the hillside, for example, is a part of the water cycle that includes the run-off of the water into lakes and oceans, evaporation, condensation of water vapor into small water droplets in clouds, and the precipitation of drops of water from the clouds. Similarly, the grains of sand that are washed into the sea are a part of the rock cycle that includes the erosion of the soil from the hillsides, the settling out of the soil particles in lakes or oceans, the formation of rocks, the twisting and perhaps even melting of rocks, the upheaval of rocks to form new hills and mountains, and the subsequent erosion of the hills and mountains. Young people should be helped to see how the phenomena that they study fit into these broad cycles.

Experiences related to conservation should be developed when they are clearly relevant to the area of science being dealt with. Instruction related to soil conservation, for example, should be developed in relationship to the study of the earth's surface. Children should become aware of some of the conditions under which soil erosion takes place, the effects of erosion, how it can be prevented or minimized, and what can be done to restore the soil after serious erosion has taken place. Children should see how soil erosion affects everyone, including the city dweller. They should learn how to recognize erosion on the playground, along river banks, the shores of lakes, in parks, and along the sides of roads. If it is possible, they should take responsibility for the prevention or control of erosion on some public land such as a playground or park.

The emphasis in the development of this area of science should be on the study of the rocks and minerals, weather and climate, land forms, soil, and surface features to be found in the local region. The pupils should have some field experiences, in which they have a chance to go out and study the phenomena of the local environment. Samples of local rocks and minerals can be collected and studied, maps of the region should be used, records can be kept of local weather conditions, nearby land forms should be visited and explanations sought, and the resources of local museums and scientific societies utilized. This is an area of study in which the learning should not come from books alone, but also from direct experiences with the concrete features of the earth's surface and its atmosphere.

If children are to have first-class instruction in this area of science, teachers must become familiar with the geology and the meteorology of the local region. There are geological maps and descriptions and explanations of the land forms for many regions of the United States. These materials should be made available to all teachers. The staffs of museums and governmental agencies, and the members of local scientific societies can help provide the background information about local geological and meteorological features, suggest field experiences, and recommend resource materials for teachers that are essential if children are to have significant learning experiences.

The study of rocks. What kinds of rocks are found in the neighborhood? Children can bring in samples of the various kinds of rocks found around their homes. These rocks can serve as a basis for the study of this unit.

When children are asked to collect materials, the teacher should stress the principles of conservation that are applicable. A basic rule of conservation is that, "Usually nothing, whether it be a rock, plant, or animal, should be collected if its removal makes a significant change in the environment." If there are countless pebbles on a beach, it is perfectly all right to pick a few of them for closer examination. Obviously, it would be wrong, however, to chip off part of a rock formation such as the Great Stone Face. At an early age children should be led to ask themselves, "Will collecting this object make a significant difference in the environment?"

The rocks that the children collect can be examined in terms of a number of physical characteristics. Is the rock made up of smaller particles such as small grains of sand or lime? How large are these particles? Some of these small grains can be scratched off and examined with the aid of a magnifying glass. They may also be compared with particles of soil found near the rock. What is the color of the rock? Are all the particles in the rock of the same color? Is the rock hard or soft? Samples of rocks can be scratched against each other as well as against glass, steel, and copper. The harder material will always scratch the softer. Are there layers in the rock? Fossils? These observations will help in determining how the rock may have been formed and how it can be used.

One of the important steps in science is to classify objects and events. Similar objects and events are grouped together. However, all systems of classification depend upon some basic characteristics. Plants are usually classified in terms of structure, minerals according to physical characteristics, and domesticated animals, such as horses, in terms of how they are used. Other ways of classification can be, and often are, invented.

At first, young children can be led to classify their rocks according to where they were found, i.e., they will use a geographical basis for classification. We may recall at this point that geologists have named many formations after type locations. When classifying their rocks, children should be led to consider the basis for their classification and encouraged to suggest other and perhaps better ways of systematizing their materials. From this they may progress to some understanding of how scientists deal with this phase of their work.

Rocks are usually classified first on the basis of how they have been formed. Igneous rocks have been formed from molten material that has cooled. Sedimentary rocks have been formed from the sediment that settled to the bottom of lakes or seas. Metamorphic rocks have been formed from igneous or sedimentary rocks as a result of heat and/or pressure exerted upon them. With young children this is usually about as far as we go with rock classification.

But pupils can study certain principles that operate in the formation of rock layers. They can see how various sized particles settle out as sediment when soil is poured into a jar. They can observe what happens to layers of material such as sheets of paper, when sideward pressure is applied. Such activities can help them gain a better understanding of the rocks they are studying.

In most communities, rocks are used in a variety of ways: buildings, statues, tombstones, manufacturing, and roads. Children can examine the rocks that are used for some of these purposes. Especially, they should look for the characteristics of a particular rock that make it useful.

Important Generalizations:

1. All rocks are composed of one or more minerals.
2. Rocks have various physical properties: color, hardness, weight, size, and shape of particles.
3. In science, objects and events are classified in terms of basic characteristics.
4. Rocks are often classified on the basis of how they were formed. Igneous rocks were formed when hot, molten rock material cooled and hardened. Sedimentary rocks were formed from the soil particles that settled to the bottoms of lakes or seas. Metamorphic rocks were formed from sedimentary or igneous rocks that have been subjected to heat and/or pressure.
5. Evidences of living things of the past, called fossils, are often found in rocks.
6. Because of particular physical characteristics, many rocks are useful to man.

7. A basic principle of conservation is that rocks, plants, and animals should not be collected if their removal makes a significant change in the environment.

Key Questions:

1. What kinds of rocks are there in our neighborhood?
2. What kinds of particles are found in these rocks? What is their color? Which of these rocks are the hardest?
3. How do we believe various rocks were formed?
4. How do we believe the fossils that are found in rocks were formed?
5. What kinds of rocks or materials made from rocks are used in our classroom? Our school? Our community?

The study of soil. The study of this unit should involve an examination of the soils found in the local environment, a study of how these soils may have been formed, a survey of how soil is used, and a consideration of how this valuable resource can be conserved. From experiences with local soils children can develop basic concepts that relate to soils in general.

Small samples of soils can be collected from various places in the community. The color of the soil sample should be noted. The soil particles can be examined under a magnifying glass. The various sized particles can be separated by pouring part of the sample into a glass cylinder containing water. Children should note the organic material that floats at the top of the water, and the importance of this organic material should be emphasized. Children can use litmus paper to test the acidity or alkalinity of the soil. They should look for evidences of living things in the soil.

A profile of the soil can be seen by observing a roadcut, ditch, or river bank. If possible pupils should examine the various layers of soil and the underlying bedrock. Are the materials in the layers of soil similar to the bedrock? Special attention should be given to the top layer of soil—its thickness and composition.

Soil formation begins with the disintegration of rock. Rocks are broken down as a result of expansion and contraction when they are heated and cooled, the expansion of water when it freezes in cracks and crevices, the pressure of plant roots that grow into cracks in the rocks, erosion by particles of sand blown against the rock surface by the wind, erosion by running water, and the chemical action of weak acids in the water that come into contact with the rock. Most of these processes can be duplicated or simulated in the classroom, and in this way children can study how soil formation begins.

Another important phase of soil formation depends on the decay of plants and animals that live and die on the soil surface. The top layer, or topsoil, usually contains most of these decay products unless a large amount of leaching has taken place. This is why topsoil is generally more fertile than the underlying soil or subsoil. The pupils should learn that the formation of a fertile topsoil is a relatively slow process in nature. If the topsoil is eroded away, years must pass before another fertile topsoil will be formed. This is an understanding that all young people should have. They can then see why there is general concern about rapid soil erosion.

Soil is one of our most important natural resources, and it must be used wisely. One of the major aims of soil conservation is to conserve the topsoil in which our crop plants grow. This topsoil can be eroded by rainfall, running water, and wind. Children should become aware of the conditions under which soil erosion is most likely to occur. They should also learn the different ways in which the amount of soil erosion can be reduced. It is highly desirable that they have a chance to see various soil conservation practices, and, if possible, they should undertake a small soil-conservation project on the school grounds or somewhere in the community.

Most of the plants that we grow get minerals and most of the water they use from the soil. What kinds of mineral matter do plants need? From farmers, gardeners, home owners and fertilizer dealers, children can find out what kinds of fertilizers are added to the soils in their community. They can experiment with growing plants in fertilized and unfertilized soil. This project should be set up as a controlled experiment, and the children should learn how to control all the variables but one.

The study of how plants get water is also important. How far into the ground do we have to dig before we find moist soil? How does the water move up through the soil? Through what kinds of soil does water sink the fastest? How deep into the soil do the roots of some common plants penetrate? What are the ways that we can add water to the soil when it becomes dry? Children can investigate most of these questions through simple experiments using improvised apparatus. In the process, they will learn more about the soil in their community and, perhaps of greater importance, they will learn more about how questions and problems in science are dealt with.

Important Generalizations:

1. Soils are formed from rocks through the action of air, water, moving objects, living things, and chemical substances; and from the decayed remains of plants and animals.
2. A long period of time is needed for the natural development of fertile topsoil.
3. Running water and wind carry soil from one place and deposit it in another.
4. The amount of soil erosion can be reduced by covering the soil with plants, by reducing the rate of flow of running water, and by minimizing the effects of wind.
5. Most plants get the minerals and water that they need from the soil.
6. If there are not enough of the right kinds of minerals in soil, they have to be added as fertilizers.
7. The rate at which water moves through soil depends to a large extent upon the size of the soil particles.

Key Questions:

1. What is soil made of?
2. How is soil formed?

3. How does water move through the soil?
4. What kinds of soil do you find as you dig down into the ground?
5. How is soil eroded?
6. How can the amount of soil erosion be reduced?
7. What is there in the soil that is used by plants?
8. How can soil be made more fertile?

Weather and climate. Weather consists of the changes that take place in the air around us. Wind, rain, snow, fog, clouds, and mist are examples of weather phenomena. Climate, on the other hand, may be described as the average weather for any particular place over a series of years. A region may have a wet, dry, hot or cold climate depending upon its average weather.

The instruction in this unit should be built on the experiences pupils already have had with the air and atmosphere. Many children may know that air is a substance, exerts pressure because of its weight, expands when heated, contracts when cooled, and contains water vapor. In this unit they will learn how these characteristics of air become important factors in determining our weather.

Energy from the sun is a key factor in bringing about the changes in the atmosphere that are called weather. Various areas of the earth's surface are heated unequally. Land surfaces, for example, are heated more quickly than areas covered by water. They also lose heat faster. Energy from the sun brings about the evaporation of water. These processes lead to the movement of air (winds), formation of clouds, and various kinds of precipitation.

With the help of wind vanes and anemometers children can study winds. When standing with their back to the wind, the low pressure area is usually to their left, because winds around a low pressure area usually move counterclockwise. Bad weather is often associated with low pressure areas. By noting the shift of wind direction pupils can trace the movement of the low pressure area. They can correlate their observations of the changes in wind direction with changes in air pressure as indicated by a barometer.

Pupils should also observe and study different kinds of winds. "Dust-devils" are examples of small tornadoes. Do the "dust-devils" spin in a clockwise or counterclockwise direction? In what direction do they move across the land? Reports and records of tornadoes should also be studied. These violent storms are somewhat like the "dust-devils," but they are, of course, of much greater magnitude and the winds blow with much greater force.

Water is an important factor in weather. A number of simple but important science activities can lead to a better understanding of how water can change from a solid to a liquid and to a vapor. Children should consider these changes as examples of changes of state. Cloud formation can be studied and simulated in simple activities. Various kinds of clouds can be observed and their meaning in terms of weather changes learned. The conditions under which water will be precipitated out of clouds can be investigated. The movement and changes in the state of water should be seen in terms of the water cycle. The water cycle is represented by an inclusive generalization that brings into relationship the changes and movements of water in the atmosphere as well as on the surface of the earth.

Keeping a record of the local weather is one of the science activities that can be carried on with profit throughout the school year. However, it should not be mere record-keeping. The observations should be used to gain a better understanding of the changes that take place in the atmosphere. Children can keep records of wind speed and direction, kinds of clouds, amount of sky covered by clouds, rainfall, temperature, and barometric pressure. They can try to find out the conditions under which they can expect fair weather and which conditions indicate future changes in the weather. By understanding the basic processes at work in the atmosphere and noting the atmospheric conditions that usually are associated with certain kinds of weather, children can become fairly good prognosticators of local weather, sometimes rivaling amateur forecasters.

Some of the factors that influence climate should be identified. For example, climate will depend on location upon the surface of the earth. Places in the far north or south will usually have a cold climate while places nearer the equator will usually have warm climates. Other factors that influence climate are large bodies of water, mountains, ocean currents, altitude, and prevailing winds.

Children should try to get information about their local climate. Data about annual rainfall, average temperatures, and length of growing season are especially valuable. Such information about local climatic conditions can be obtained from almanacs, the local weather stations, and reports of the United States Weather Bureau and the Department of Agriculture.

Important Generalizations:

1. The atmosphere is made up of the troposphere; the stratosphere and the ionosphere. Changes in the atmosphere that we call weather take place in the troposphere, which is the atmospheric region nearest the earth's surface.

2. The sun supplies the energy that is needed to bring about changes in the atmosphere.

3. Air expands when heated, and contracts when cooled.

4. Warm, moist air is less dense than dry, cool air. The cool, dry air settles toward the surface of the earth and pushes the warm, moist air away (usually up).

5. When water vapor is cooled to a certain point, it condenses into liquid.

6. All water on the surface of the earth and in the atmosphere (whether it be in a solid, liquid, or vapor state) is in some phase of the water cycle.

7. Various areas of the earth's surface and different regions of the atmosphere are heated unequally. This unequal heating, and the evaporation of water, leads to differences in air pressure.

8. Differences in air pressure and the rotation of the earth are

among the factors that determine the direction and speed of the winds.

9. The amount of water that can be held by the air depends on the air temperature. Warm air holds more moisture than cold air.

10. The climate of an area is influenced by its location on the surface of the earth, by large bodies of water, mountains, ocean currents, altitude, and prevailing winds.

Key Questions:

1. How is air heated? What happens when air is heated? Cooled?
2. How does water enter and leave the atmosphere? What happens when water enters the air?
3. How does heating or cooling affect the amount of water that can be held by a mass of air?
4. Which is warmed the fastest: equal amounts of sand, dark soil, or water? Which cools the fastest?
5. What are winds, and how are they produced?
6. How are clouds formed? How can they be used to forecast weather?
7. What kinds of conditions lead to rain? Snow? Hail? Frost? Dew? Fog? Smog?
8. What happens when a mass of cold air meets a mass of warm air?
9. What instruments are used by a weatherman to help in forecasting weather? How is a forecast made?
10. What causes climates to be different in various parts of the world?

The earth's changing surface. The surface of the earth is in contact with the atmosphere and the hydrosphere. Forces at work in both of these spheres affect the surface of the earth. The lithosphere—the more solid part of the earth—is not static and unchanging. There are powerful forces at work within the earth that affect the surface layers.

Some parts of the earth's surface appear to be rising. We believe, for example, that the Rocky Mountains are still being pushed upward very slowly. The region north of Lake Superior is also believed to be rising slowly. Much of the coast line in northeastern North America, on the other hand, is believed to be sinking. The Gulf coast apparently is rising. It should be made clear to the pupils that these changes are not catastrophic, but are taking place slowly over a long period of time.

In many places there are active volcanoes. In the Hawaiian Islands, for example, there are periodic outpourings of lava that significantly change the surface of the earth. A Mexican farmer once woke up to see a pile of cinders and volcanic ash forming on his farm. This pile has now grown into the mountain Parícutin. The process of volcanism is one of the ways in which various areas on the surface of the earth are built up.

The earth's surface is worn down by erosion. As a drop of rain strikes the surface of the land, a few particles of soil are jostled fractions of an inch down the hillside. This is repeated countless times in each rainstorm. The thin sheets of water that flow down the hillside carry away a little of the surface of the land each time it rains, and lead the farmer to wonder why more rocks appear in his fields after he had removed all he could find the year before. Rivulets, streams, and rivers carve out little ditches or grand canyons as they roll ever-downward toward the sea. In every community children can see ways in which the surface of the earth has been changed by the work of running water.

The winds, too, sweep the surface of the land and carry away particles of rocks and soil. The soft rocks wear away more rapidly, sometimes leaving oddly shaped remnants that have been etched by the winds. Where it is possible, children should examine wind-swept rocks to see which parts wear away first. The sand and soil carried away by the winds are deposited elsewhere. Much of the rich soil of the Midwest was deposited there by the winds. Such soils tend to stand in almost perpendicular banks when a river cuts through them, or when workmen dig a trench. Samples of soil should be examined, and imaginative children will speculate about their origins.

Most of the northern half of the North American continent was covered at various times by the great glaciers of the Pleistocene epoch. In many areas the scratches and grooves made by rocks in the slowly moving ice sheets are still in evidence. What the glaciers plucked or scraped from one place on the earth's surface was deposited elsewhere as the ice melted. In many places, children can study soil that is a mixture of small particles, oval-shaped pebbles and huge boulders. These soils could only have been deposited by glaciers. In regions that have been glaciated, the effects should be studied. In all situations it is possible to set up various activities involving ice, rock, soil, and water which will show how glaciers can change the surface of the earth.

We believe that the various forces in the crust of the earth are in balance. For example, when a large ice sheet melts, the downward forces acting on the earth's crust in that region are reduced, and the surface of the earth will tend to rise. This is the most commonly accepted explanation for the rising of the earth's surface north of Lake Superior. To compensate, the surface will sink somewhere else. Under the Gulf of Mexico, for example, the deposition of millions of tons of sediment each year increases the downward force. This force is believed to be transmitted through the crust, and the surface of the earth elsewhere, perhaps in the Rocky Mountain region, will be pushed upward. This theory of the balance of forces in the earth's crust is called *isostasy*. It is the broad generalization that serves to explain many of the changes that take place at the earth's surface.

In the study of this unit, children should improve their skills in using maps. It is especially important that they use maps of the local region, and begin to see how land formations and configurations are depicted on the maps. They can also begin to use and interpret geological maps.[2]

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[2] Geological maps are available for most regions of the United States. Request free index maps of your state from the Director, United States Geological Survey, Washington, D.C. The index map will indicate which quadrangle includes the local community.

Important Generalizations:

1. The surface of the earth is being constantly worn away by the action of wind, water, and ice.
2. Some parts of the earth's crust are being pushed upward, while other parts are sinking.
3. There is believed to be a balance of forces within the earth's crust. Forces are transmitted through the crust. A downward force in one place is compensated for by an upward thrust elsewhere, and vice versa.
4. Soft rocks will be worn away faster by wind and water than will hard rocks.
5. Melting ice will deposit soil, pebbles, and boulders as an unassorted mixture. Materials deposited by wind and water, on the other hand, tend to be sorted so that similar particles are together.
6. Various land forms and the different elevations of land can be shown on a map.

Key Questions:

1. What are some of the ways we think mountains have been formed?
2. How can winds wear away a hard rock?
3. What happens to a particle of soil that is washed off the top of a mountain?
4. How are glaciers formed?
5. How do glaciers change the earth's surface?
6. What kinds of materials come up through volcanoes?
7. What will eventually happen to a mountain?
8. How has man changed the surface of the earth?

History of the earth. How can we find out about the past? Children may say that we can read about what happened in history books. But how can we find out about the past long before there was anyone around to see and record what happened? These are questions that will lead youngsters into considering how we can find out about events that took place long ago.

The early history of the earth is recorded in the rocks of the earth's crust, rather than in records kept by observers. Some of these rocks have been formed from sand and soil that have settled to the bottom of lakes and seas. In the Grand Canyon, the Colorado River has exposed layers of rock that were deposited as sediment more than a billion years ago. By examining these rocks and the fossils and other materials found in them, we can learn a great deal about conditions on the earth at that time. Children should have the experience of examining sedimentary rocks in order to get information about the period when the rocks were formed. Rock samples containing fossils are especially valuable as sources of information. From the fossils children can gain some clues as to the nature of life in the lakes and seas of prehistoric times.

Considerable information can also be gained from the igneous rocks formed from molten rock material. Pupils can dissolve salt or other materials in hot water and compare the size of the crystals that are formed when the solutions are cooled quickly in a refrigerator and when they are cooled very slowly. Larger crystals are formed when the solutions are cooled slowly. Similarly, when molten materials cooled slowly, rocks with larger crystals were formed than when the molten materials were cooled quickly. Molten materials cool more slowly deep within the earth than they do at or near the surface. By examining the crystals in igneous rocks, children can judge whether the rock sample was formed at the surface or deep within the earth's crust.

Metamorphic rocks are rocks that have been changed by heat and pressure. Some of these changes can be studied through such activities as heating clayey mud in a pan and observing the changes that take place. In areas where there are rock formations that have been twisted and bent, an attempt can be made to hypothesize what the nature of these forces must have been.

How old are various rocks? In sedimentary rock formations, the lower layers are older than the layers above unless the layers have been folded or otherwise displaced. By measuring the thickness of various layers, and through a knowledge of the rate at which sedimentation takes place, scientists can make a rough determination of the age of sedimentary rocks. Children can make similar observations of the formation of layers of sediment in jars filled with water and soil. Now, however, a new way of determining the age of rocks is by ascertaining the ratio between the amount of a radioactive element in a rock and the stable product of the radioactive decay of that element. For example, in 4½ billion years, half of the radioactive uranium in a rock will decay to lead. By comparing the amount of lead in a rock sample with the amount of uranium, a fairly accurate determination of the age of the rock can be made. Children can gain a general understanding of these procedures for determining the age of rocks.

The earth is believed to be five or six billion years old. The first rocks were probably igneous rocks. Many of these rocks have been worn away by the work of the winds, running water, and sheets of ice. Mountains have been thrust upward, to be worn away by erosive forces and eventually replaced by other mountains. Various parts of North America have been under water at one time or another, and a large portion of the continent has been covered by ice. These are a few of the many changes that have taken place in the history of the earth.

The history of the earth has been divided into long divisions of time called *eras*. Eras, in turn, are divided into periods, periods into epochs, and epochs into ages. Each of these divisions of time is characterized by certain kinds of rock. For example, the rocks at the bottom of the Grand Canyon are believed to be from the Archeozoic era, which is the era farthest removed from us in time. In different geologic eras and periods, different kinds of life were dominant. In the Triassic period reptiles dominated the living world. Children will not master the details of the earth's history. However, they should become aware of the broad scope of that history, and that various divisions of time are characterized by certain geological and biological events. The emergence of life in the seas, the movement of some forms of life from the seas to dry land, and the continuing evolution of living things are also important developments in the history of the earth. The study of earth history provides a background for the study of the unit on "Adaptations of Living Things."

Important Generalizations:

1. The general scientific principles that are used to explain phenomena that occur today can be used to explain phenomena that have occurred in the past.
2. Much of the early history of the earth is recorded in the rocks of the earth's crust.
3. Lower layers of sedimentary rock are usually older than the layers above.
4. Larger crystals are formed when solutions cool slowly than when cooling is rapid.
5. The age of rocks can be determined by studying the layers of sedimentary rocks above, and by determining the ratio between the amounts of a radioactive element and the products of its radioactive decay.
6. The earth is believed to be five or six billion years old.
7. During the time since the earth was formed many important changes have taken place: mountains have been pushed up and then worn away; many areas that are now dry land were once covered by the sea; and large areas have at times been covered by sheets of ice.

Key Questions:

1. How was the earth formed?
2. What changes have taken place in and on the earth since it was formed?
3. How can we find out about what has happened in the past?
4. How can we tell where and how an igneous rock was formed?
5. What can we learn from fossils concerning life in the past?
6. How can the age of rocks be determined?

The earth's resources. Like the atmosphere and the hydrosphere, the lithosphere is a source of raw materials that can be used to make the things we need and want. The rocks, minerals, and fuels that we take from the earth are used for buildings, roads, as a source of energy, and as a raw material with which we make tools, machinery, automobiles, and even some of the clothes that we wear.

Rocks are large masses of minerals. Most rocks are composed of a number of minerals, but there is no consistent ratio between these minerals. Granite, for example, is composed of the minerals feldspar, quartz, mica and, at times, traces of several others. The amounts of these minerals in various samples of granite will differ. Other rocks, such as marble (which is composed almost entirely of calcium carbonate), are largely made up of one mineral.

When rocks contain a sufficiently large proportion of some valuable mineral, the rocks may be mined so that the prized mineral can be extracted. The taconite rock found in northern Minnesota is mined, crushed into small pellets, and processed to extract iron which can be used in the making of steel. Usually, the percentage of a mineral in a particular rock and the value of the mineral determine whether it is worth mining. A rock would have to contain a fairly high percentage of an iron compound to make mining profitable, but a rock with a much lower percentage of gold might be very much in demand.

Unlike rocks, minerals are made of only one kind of material. In fact, chemical formulas can be written to show the definite composition of a mineral. Quartz, mica, beryl, feldspar, copper and gold are examples of minerals. Strictly speaking, ice is also a mineral. Some scientists also classify coal and oil as minerals.

Some minerals are processed to yield valuable substances. Iron is extracted from such ores as the powdery hematite scooped out of the Mesabi Range in northern Minnesota. Lead is obtained from the mineral galena and copper from chalcopyrite. Minerals are primarily important because of the substances that can be extracted from them.

Minerals are concentrated by various natural processes. About 8 per cent of the earth's crust is made up of aluminum, but in only a few places is the aluminum-bearing mineral bauxite sufficiently concentrated to make mining worthwhile. Many plants and animals help concentrate minerals. Kelp, which grows in the ocean, concentrates both iodine and potassium, and is a major commercial source of both of these elements. Water percolating through the ground will leach out those materials that dissolve easily in water, and leave behind a higher concentration of minerals that contain such important elements as copper, lead, and iron. In a molten state the heavier minerals, such as those containing iron, sink; lighter minerals, such as quartz and feldspar, tend to rise. In a similar way, when the prospector pans for gold, the light materials float away, and the heavier gold remains. Children can demonstrate how minerals are concentrated by leaching and by weight.

Since minerals have a fairly specific chemical composition, they have definite physical characteristics such as color, hardness, and cleavage, which can be used in classifying them. Among the many fine activities that pupils can undertake in this area is the collection and identification of various minerals, and the study of their physical characteristics.

Important resources from the earth include such fuels as coal, oil, and gas. All these fuels are believed to have been formed from the remains of plants and animals that lived long ago. In fact, the energy obtained from these fuels originally came from the sun. Pupils should be helped to trace this energy back to the sun, and to study some of the processes that may have been involved in coal and oil formation. They can also make certain elementary studies of coal and oil, to find some of their physical and chemical characteristics.

Youngsters should develop an understanding of the difference between renewable and nonrenewable resources. Our forests are a renewable resource because new trees can be planted and grown. The loss of trees through forest fires or disease is grievous but not irrevocable. Minerals, on the other hand, are a nonrenewable resource; once lost they cannot be replaced. The conservation of nonrenewable resources is of special importance.

In the study of the earth's resources, the optimum utilization should be made of the opportunities provided by the local community. There are rocks and minerals to be found in almost all communities. These should be located, studied and identified. In many communities, there are people who make the study of rocks and minerals their hobby. Usually they are delighted to help children and young people in their studies. Museums have interesting and informative displays and collections. The state geologist and the U.S. Geological Survey will have maps, bulletins, and other sources of information that children can use in their studies. This is an area of elementary school science where the focus can very profitably be on the resources to be found in the local area.

Important Generalizations:

1. Most rocks are composed of a number of minerals, and the amount of any particular mineral in a given kind of rock will vary.
2. Minerals have a fairly definite chemical composition. A chemical formula can be written for a mineral.
3. Minerals have specific physical characteristics such as color, hardness, cleavage, streak, and luster. Minerals can be identified on the basis of these physical characteristics.
4. Minerals are concentrated in the earth's crust by plants and animals; by leaching away of soluble materials; by floating of light materials; by sinking of heavy substances; and by the washing away of lighter materials.
5. The percentage of a mineral in a particular rock and its value determine whether the rock is worth mining.
6. Because minerals have a fairly definite chemical composition, some minerals can be treated chemically to get the substances we want.
7. The energy derived from fuels such as coal, oil, and gas originally came from the sun.

8. Minerals are nonrenewable resources and therefore must be used carefully.

Key Questions:

1. What kinds of materials do we find in the earth's crust?
2. How can minerals be named and identified?
3. Although most materials are found almost everywhere in the earth's crust, why are they mined in some places and not in others?
4. How are important deposits of minerals located?
5. What are some ways that minerals are separated from their ores?
6. What are some ways that metals are extracted from minerals?
7. How do we believe coal and oil were formed?
8. Why is the conservation of minerals and the materials we derive from minerals especially important?

HEALTHFUL LIVING THROUGH SCIENCE

"Health is a state of complete physical, mental, and social well-being and not merely an absence of disease or infirmity." This positive definition of health is from the preamble of the constitution of the World Health Organization (WHO). According to this view health is more than a matter of just keeping well. It is a state of "complete physical, mental, and social well-being." This is a lofty objective that defines the general aim of our work in this broad area of elementary school science.

Children should learn how to care for themselves and nurture their bodies so as to achieve optimum growth and development. A healthy body is the basic prerequisite for a happy life. Just as sickness and sadness seem inevitably linked, there is a probable relationship between health and happiness. Every individual is born with certain potentialities for growth and certain possibilities of development. Through their activities in this area of elementary school science, youngsters can learn how to achieve optimum growth and development.

Children can learn how to prevent sickness and the spread of disease. Many diseases of man are spread from one human being to another. The viruses, bacteria, and protozoa that are the bearers of disease are conveyed to us by insects, drinking water, air, or contact. Children can learn how various diseases are spread, some of the characteristics of the vectors that transmit certain disease germs and, of greatest importance, how the spread of the diseases can be prevented. As a result of such knowledge, children can protect others from sickness as well as themselves.

Elementary school pupils can learn some of their community responsibilities to help everyone achieve health. They can practice cleanliness, sanitation, and good nutrition in their school life, and in this way become better citizens in their communities. Safe drinking water, foods free from contamination, sanitary waste disposal, and air free from pollution can be provided only through the efforts of all citizens in a community.

Through elementary school science children should begin to learn the "whys" for the various things they can do to achieve health. Why is it important to eat a certain amount of food rich in proteins every day? Why is it important to remove garbage, trash, and other waste materials from the community? How does daily exercise contribute to health? Children need to know what should be done, but they also need to know why these acts are important. The explanations, of course, are scientific ones. Children learn the function of proteins in the body; that trash and waste materials are breeding grounds for flies and other insects; and that exercise helps to build muscle tone and to maintain a proper relationship between the energy taken into the body as food and the energy used in exercise. We want children to insist on knowing "why." In elementary school science they should have a chance to "find out."

In "Healthful Living Through Science," units are planned that deal with nutrition, care of the body with special attention to the senses, and community health and sanitation. Considerable emphasis is given to the broad generalizations that have been developed in the various sciences related to this area, and it is especially important that children learn how to use these generalizations in dealing with health problems.

Foods we should eat. It is obviously desirable that children learn the kinds of foods that are needed for good health. Good nutrition early in life is related to optimum growth and development. The teeth and bones are in a vital state of development and, of course, permanent teeth lost because of undernourishment can never be replaced. Furthermore, our patterns of eating are usually habitual, and most of our basic habits are formed when we are young. It is essential that children have a chance to form eating habits that can lead to a long and healthy life.

A great deal has now been learned about the food needs of the body. A daily food plan has been developed which can serve as a guide to a good diet. This plan is built around the Basic Four Food Groups:

I. Milk group of foods. Three to four cups. The most important source of the calcium needed for sound bones and teeth. Also a good source of proteins and energy.
II. Vegetable-fruit group of foods. Four or more servings. Vegetables and fruits provide us with many essential vitamins and minerals.
III. Meat group of foods. Two or more servings. These foods are the source of the protein needed for healthy muscles, blood, skin, and hair.
IV. Bread-cereals group of foods. Four or more servings. These foods are our most important source of energy. They also provide minerals and vitamins.

In the nutrition education of children three related approaches are suggested: [3]

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[3] For descriptions of a variety of promising practices in nutrition education in the elementary school see Willard J. Jacobson, Fannie Lee Boyd and Mary M. Hill, *Promising Practices in Nutrition Education in the Elementary School* (New York: Bureau of Publications, Teachers College, Columbia University, 1959).

1. Help children become aware of the kinds of foods they are eating. Pictures and names of foods can be used as children state the foods they have eaten during the day. This information helps the teacher to find out what the children's nutritional needs may be.
2. Begin to develop a concept of what foods are needed for an adequate diet. The Basic Four Food Groups can be used as an approach in teaching.
3. Widen the range of foods that children habitually eat. Children are more likely to have a balanced diet if they eat a wide variety of foods. Teachers can lead children into trying new foods that will add variety to their diets.

Important Generalizations:

1. The food we eat makes a difference. Food is necessary for life, and we can lead healthier lives if we eat the right kinds of food.

2. We should eat a certain amount of each of the Basic Four Food Groups every day.

3. We are more likely to have a balanced diet if we can eat a wide variety of foods.

Key Questions:

1. What kinds of foods do you eat?
2. What kinds of foods should we eat?
3. How can we insure greater variety in our diets?

Preventing the spread of disease. We now know how to control and prevent many of the diseases that afflict man. A century ago such diseases as tuberculosis, pneumonia, cholera, dysentery, malaria, yellow fever and polio killed or maimed millions of people every year. Children are usually deeply interested in the stories of how these diseases have been controlled or conquered, and it is well that they are for these accomplishments are among the greatest contributions of science. A study of how various diseases have been controlled will help children see how scientists have studied the diseases, determined their causes, and found ways to deal with them.

One of the great steps forward in the study and control of disease was the development of the germ theory. Many human diseases are caused by very small microorganisms such as bacteria and protozoa. Other human ailments are due to viruses. Prior to the development of the germ theory, many diseases were thought to have almost mystical origins. The germ theory made possible the scientific study of disease control. One of the important learnings that children should gain from their study of this area is that there are definite causes for human disease.

Many communicable diseases are spread from one human being to another. Some disease-causing germs are spread by sneezing and coughing, and enter the nose or mouth of a healthy person as he breathes. The tetanus bacillus enters the body through cuts in the body surface. Certain diseases such as typhoid fever, dysentery, and cholera are spread as food or water are contaminated by persons who have the infections. Probably microorganisms that cause such diseases may also be carried to the food by houseflies and similar insects. Malaria, of course, is transmitted by mosquitoes from people who have the disease to those who do not have it. In their study of this unit the pupils should gain a general knowledge of communicable diseases and the reasons why we have various public health safeguards.

The spread of such diseases can be controlled if we can prevent the infection and reinfection of human hosts. Some of the diseases spread through the air can be avoided in part by covering the mouth and nose with handkerchiefs when sneezing or coughing. Open cuts, of course, should be kept clean, and usually treated with some antiseptic to kill disease germs. Drinking water should not be contaminated with waste materials. Moreover, waste materials should be disposed of in such a way that flies cannot come into contact with them. Flies should also be kept away from the foods we eat. Children should learn these general ways in which the spread of diseases can be prevented.

In their studies in this unit, youngsters can begin to gain an understanding of the life cycles of animals, particularly insects.

Insects such as mosquitoes and houseflies go through the stages of development that are characteristic of complete metamorphosis. These insects are particularly vulnerable at certain stages in their life cycles. The eggs of the housefly usually are incubated in piles of horse manure. If the manure is spread out on fields to dry, the number of houseflies in the area will be reduced. The larval and pupal stages of mosquitoes live in water. If puddles, stagnant pools and marshes are drained or sprayed with a substance such as oil so that the larvae and pupae cannot get air, most mosquitoes will be prevented from reaching adulthood. A knowledge of the life cycles of insects can help children understand various procedures taken to prevent the spread of diseases in which insects serve as vectors.

The human body can be made resistant to certain specific diseases. Pupils should become familiar with vaccination and inoculation. Certainly they should learn why these procedures are important, and many of them can begin to get an understanding of how conferred immunities will protect the body against disease.

There are a variety of potential approaches to teaching in this area. Some of the common diseases are sometimes studied with emphasis on characteristics of the diseases, symptoms, how they are transmitted, and how they can be prevented. Many excellent teaching materials are available for use in this approach. Children are also interested in the history of the conquest of various diseases. Some teachers have developed this unit in relation to actual outbreaks of disease in the home community. But whatever the approach may be, children should learn the simple but fundamental measures that can be taken to reduce the incidence of communicable disease.

Important Generalizations:

1. All human diseases have natural causes. Many diseases are caused by viruses or small microorganisms such as bacteria and protozoa.

2. Some diseases are spread from one human being to another. But we should not forget that we share some diseases with wild and domesticated animals.

3. The spread of disease can be controlled by preventing the transfer of the organism causing the disease.

4. Insects, including many of those that carry human disease germs, are particularly vulnerable to destruction during certain stages of their life cycles.

5. The general health of the human body can be maintained through good nutrition, adequate sleep, and cleanliness. Immunization provides defenses against certain specific diseases.

Key Questions:

1. What are the causes of various diseases?
2. Before the development of the germ theory of disease, what were some of the explanations that were given for disease?
3. What are some of the ways in which we can protect ourselves from disease?
4. What are some of the ways in which we can prevent the spread of communicable diseases?

Our ears and hearing. The work in this unit should be correlated with the study of sound and music, as well as with studies of energy and energy sources. Some of the work in these units may be fused to form a large area of study.

The body receives information about its environment through its special senses. Actually, the information is impressed upon various forms of energy. Sound energy, for example, is received in the ear. The various modulations of the sound energy are interpreted by the brain.

Children can learn how the ear is constructed and the process whereby it converts sound energy into a form that can be interpreted by the brain. The ears are devices that convert sound energy into mechanical energy in the form of small movements of the eardrum and the bones of the ear. This mechanical energy is then converted into the energy of nerve impulses. Nerve impulses are conducted to the brain by the auditory nerves. In the brain the incoming impulses are interpreted as information. Children should see the ear as a device for converting one form of energy into another.

Children should, of course, learn how to care for their ears. The ears can be damaged by sharp, loud sounds, and by sharp, pointed objects that young people may be disposed to insert into their ears for one reason or another. Sneezing and hard blowing of the nose can force mucus containing germs up through the Eustachian tubes and infect the ears.

Important Generalizations:

1. The body receives information about its environment through its special senses. The ear is the organ for receiving sound energy.
2. In the ear sound energy is converted to mechanical energy, and the mechanical energy into nerve impulses.
3. The pattern of the nerve impulses that reach the brain through the auditory nerves is interpreted by the brain as information.
4. The ear is a delicate organ that should be protected from sharp, loud sounds, pointed objects, and from infection.

Key Questions:

1. How do we receive information about our environment?
2. What structures are found in the human ear?
3. How does the eardrum convert sound energy to mechanical energy?
4. What is the range of sounds we can hear? Can some people hear sounds that other people cannot?
5. How can we protect our ears from harm?

Our eyes and sight. The study of eyes and sight is closely related to the unit on light and photography. The energy of light is received by the eyes, and the study of the camera can help us to understand how the eyes operate.

The eyes are the organs of the body that convert light energy into nerve impulses. Briefly, light enters the eye through a small aperture called the pupil. The image is projected upon the retina at the back of the eye by a lens that thickens or flattens out in order to bring the image into focus. In the retina the light energy is converted to chemical energy and then to nerve impulses. The nerve impulses are conducted to the brain via the optic nerves.

We see objects because of the light given off by them, or by the light they reflect. Actually, the eye is a very sensitive organ. It can see, for example, the light given off by a candle miles away. The amount of light reaching the eye from the candle is indeed very small, yet it is enough so that the eye will generate nerve impulses that can be interpreted by the brain. We detect the form and color of many objects by the light that is reflected by them to us. Since some objects reflect only certain wave lengths of light, we see them as being colored.

The structure and operation of the eye can be compared to that of the camera. Many teachers have children make simple pinhole cameras to show how images are formed on a ground glass at the back of the camera. Later, children can examine a box camera and a folding camera. Pupils should be led to discover the similarities and the differences between their eyes and these cameras. The similarities and differences can be explained more effectively if models or charts of the eye are used.

Children should become aware of the various factors that affect our sight. For example, we can see many more stars on a cloudless night out in the country than we can in the city. The lights of the city are so bright that it is difficult to see any but the brightest stars. If we stare for a few minutes at a spot of red light in a darkened room, and then change it to a white light, the spot will appear green rather than white. Actually, the part of the retina that is sensitive to red light becomes fatigued, and is not as sensitive to the red part of white light as it would normally be. What we see is affected by the condition of our eyes, our minds, and previous experiences. To show this, some teachers have had several children view the same scene and then later describe it. The variations among the descriptions are usually striking.

It is important to take good care of the eyes. Adequate light directed in such a way that there is a minimum of glare is essential for reading, sewing, and other work. One should never look at a source of extremely bright light such as the sun. Obviously, the eyes, like the ears, should be protected from injury by grit, dirt, and pointed objects.

Important Generalizations:

1. The eyes convert light energy to chemical energy to nerve impulses that are conducted to the brain by the optic nerves. The brain is able to interpret patterns of nerve impulses as information.

2. We see objects because of the light that is given off or reflected by the objects.

3. What we see is affected by the condition of our eyes, our minds, and our previous experiences.

4. We should provide good conditions for vision when doing fine work. The eyes should be protected from extremely bright light and from injury by dirt, grit, and physical objects.

Key Questions:

1. What kinds of objects can we see? What are some of the limits to our vision?

2. How can an image be focused on a ground glass? How is an image focused on the retina?

3. If the image on the retina is upside down, why don't we see the world around us as being upside down?

4. Why do two people who look at the same scene usually see different things?

5. What are some of the common defects of the eyes and how can they be corrected?

6. How do glasses help some people to see better?

7. How can we protect our eyes from various injuries?

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Good nutrition. Good nutrition means eating the foods we need to achieve health and optimum growth and development. Good nutrition is one of the prerequisites for the complete physical, mental, and social well-being that is defined as health by the World Health Organization. Nutrition scientists have determined the kinds of foods that most people need to achieve good health. In this unit, pupils should learn how to use some of the important findings of the science of nutrition.

In the intermediate grades children should gain a deeper understanding of what kinds of foods should be eaten and why. There should be some consideration of the major sources of foods, and the functions of these foods in our bodies.

All our foods can be traced back to green plants. Children can learn about food chains that start with the green plants, include animals such as cattle, and end with man. Usually, it is useful to classify common foods as to whether they are primarily proteins, carbohydrates, or fats. The various ways of processing and preserving foods should also be studied, with particular attention to the scientific principles involved. This study can lead to a number of important laboratory activities.

Children should become aware of the three major functions of foods in the body. Foods supply the energy the body needs to operate the various organs, for movement, and to keep the body warm. The calorie as a unit for measuring energy can be introduced, and children can begin to find out the relative energy values of various foods. Foods also are needed for growth and repair of tissue. In eighteen years or so an eight-pound baby may become a 200-pound fullback. Proteins are especially valuable for the growth and repair of tissues. Some foods, especially vitamins and minerals, are needed for the regulation of various body activities.

To help people to eat so that they get sufficient quantities of the various kinds of foods, simple guides to eating have been developed. One of the most widely used guides is the "Basic Four Food Groups" described on page 72. Most people can get the foods they need by eating the foods recommended in this guide.

Foods become soluble in our bodies. Through the process of digestion, foods are changed into a form in which they can pass through the walls of the digestive tract into the bloodstream and be used by body cells. Children learn what some of these changes are. In fact, they can duplicate some of these changes in simple experiments with foods. Obviously, they should learn the ways, such as proper chewing of food, in which they can favor the digestive processes.

Youngsters should learn that the food they eat makes a difference. They can study the effects various foods or the lack of certain nutrients have on plants and animals. Because rats have dietary requirements that are similar to man's, controlled studies in which various kinds of diets are fed to rats are especially instructive. In such studies, children can see the rather striking changes that take place if rats do not get enough of certain essential nutrients. Equally striking changes take place when rats are put back on an adequate diet. An important aspect of such an activity is that the pupils gain a better understanding of the controlled experiment and how it can be used for investigations in science.

Important Generalizations:

1. The food that we eat makes a difference in how we live and grow.
2. We need energy-giving food for movement, to operate the various organs of the body, and to keep the body warm. We also need food for the growth and repair of tissues, and for the regulation of various body processes.
3. Basically, all our foods have their origins in green plants.
4. Foods can be classified as carbohydrates, proteins, and fats.
5. By following such guides to eating as the "Basic Four Food Groups" most people can be assured of their basic food requirements.

6. The foods we eat are changed through the process of digestion into a form that can be used by body cells.

7. The controlled experiment is a valuable tool for investigation in science.

Key Questions:

1. How do the foods that we eat affect our health and well-being? How do we know?
2. What uses does the body make of food?
3. What happens to the foods that we take into our mouth?
4. How can we make certain that we are getting enough of the right kinds of food?
5. Where do our foods come from? What do we do to foods before we eat them? Why?
6. How can we find out whether eating or not eating certain foods makes a difference?

Community sanitation and health. Community sanitation is necessary in order to safeguard the health of each individual. Diseases often are spread from one individual to another. To prevent the spread of such diseases, steps usually have to be taken on a communitywide basis. Measures to insure a safe food supply, pure drinking water, clean and efficient removal of wastes, and the control of pests usually cannot be carried out by the individual citizen but must be undertaken by the community. This is especially true in urban areas. Children need to learn the scientific principles involved in these procedures so that they will understand these community actions and cooperate in the programs.

It is important that the foods we take into our bodies be free of the organisms that cause disease and putrefaction. Most microorganisms can survive only under certain conditions. Children can study these conditions by growing microorganisms on agar surfaces. They should also study the steps that we take to prevent microorganisms from contaminating foods and from multiplying in foods. All the methods of food pasteurization and preservation are based on tested scientific principles. Pupils can begin to gain an understanding of these principles, and can use and study them in various science activities carried out in the classroom.

Similarly, the water that we drink must not be contaminated with harmful organisms. Most of these harmful organisms come from human wastes. What is the source of the community's drinking water? How does the community prevent its drinking water from being contaminated with these wastes? If the water is polluted, the contaminating material can be removed in water-treatment plants and the harmful organisms killed with such chemicals as chlorine. How is the drinking water in the community treated? What basic scientific principles are involved in this treatment? In some communities children can also find out how water is treated to help prevent tooth decay.

A community's waste materials must also be disposed of in a sanitary way. Liquid sewage is often treated in very much the same way that drinking water is treated to remove contaminants and kill harmful microorganisms. In what ways is the sewage from the community treated? This may lead children into a consideration of such scientific principles as flotation, sedimentation, filtration, and chlorination. Garbage and other solid wastes are usually disposed of so that they will be subjected to decay and decomposition. Children can carry out simple experiments to study these organic processes. Some waste materials are dispersed into the atmosphere as smoke and gases. A number of activities can be undertaken to study how the air is polluted, what kinds of materials are in the air, and how the amount of air pollution can be reduced.

Insects, rodents, and similar pests must also be controlled on a communitywide basis. Houseflies, mosquitoes, and rats, for example, can travel throughout the community, and therefore their control becomes a general problem. One of the most effective methods of teaching in this area is to use an ecological approach. Children study the physical characteristics of the pests, their habits, and the nature of the environment in which they thrive.

Various governmental agencies have responsibilities for maintaining community sanitation and health. Foods are inspected, food handlers are licensed, water is tested, wastes are collected, and research is carried out to find better ways of protecting the health of citizens. Children should gain an understanding of the work of these agencies and the reasons for their various regulations.

A community study approach should be used in this area of the science program. Children should become acquainted with the problems of health and sanitation in their own community, and the various steps that are taken to try to achieve a community where healthy living is possible. As in other important areas of science, they need to understand the abstract generalizations, but they also need to learn how these generalizations are applied in dealing with actual problems.

There should also be considerable laboratory work associated with this unit. Pupils can study how substances decay. They can compare various kinds of water, and learn how microorganisms attack foods. They can have experiences in using scientific principles to preserve foods. In these studies pupils should have access to microscopes and learn how to use them.

Important Generalizations:

1. Many human diseases are caused by microorganisms that are passed from one human being to another through food, water, or by various pests.

2. Microorganisms thrive only under certain environmental conditions. If they do not have such conditions they usually die. Because of this, many of them will be killed by heating, freezing, drying, or through contact with chemicals.

3. Microorganisms contribute to the decay and decomposition of wastes.

4. Substances heavier than an equal volume of water tend to sink, substances that are lighter tend to float.

5. Solid materials suspended in a liquid can be removed by passing the liquid through a filter, such as a bed of sand.

6. All animals, including various pests, are adapted to live under certain environmental conditions. If we know the physical characteristics of various pests, their habits and the nature of the environment in which they thrive, we are in a better position to control them.

Key Questions:

1. What are the major problems of health and sanitation in our community?
2. What happens when substances decay?
3. What steps have to be taken to insure a pure water supply?
4. In our community what regulations govern the production and handling of foods?
5. How are foods canned? Frozen? Dried? Irradiated?
6. What insects can be found in the buildings of the community? How can these insects be controlled?

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THE EARTH IN SPACE

In their study of the earth in space children should develop a concept of the nature of the universe in which they live. They will study the atmosphere and hydrosphere of the earth, the place of the earth in the solar system, the relationship of the solar system to the Milky Way Galaxy and the universe, and the ways we explore outer space. Probably all youngsters and adults have some concept of the place of the earth in space. However, it is important that pupils develop concepts with regard to the nature of the universe that are consistent with the view of the universe that has been developed by scientists.

The study of the universe opens up an almost unlimited field of exploration for everyone. The astronomer, geophysicist, oceanographer, meteorologist, astrophysicist and space scientist devote much of their efforts to the development of a more detailed and consistent picture of the universe. However, every individual is also engaged in developing for himself a concept of the universe in which he lives. Children and most adults are dependent upon specialists for information about the universe, and for the theories that give meaning to this information. But young people need a background of experience in this area in order to gain access to the information, understand the theories, and begin to build their own concepts.

In this area of science it is especially important that children have a chance to relate their direct experiences with the cumulative knowledge of mankind. For example, as children view the sun apparently moving across the sky from east to west every day, they might very well conclude that the sun revolves around the earth once each day. In fact, this was the accepted explanation for centuries among learned men. But today pupils can relate their observations to what scientists know about the solar system. Then they will find that a more consistent explanation of the apparent movement of the sun is that the earth rotates on its axis.

In the modern view, we live in a vast, relatively unexplored universe. To some, this concept of the universe may seem to diminish the stature of the human being. In the past, man viewed himself as being a unique organism living at or near the center of a very limited universe. Today we are forced to realize that the earth is a medium-size planet revolving around the sun. The sun is one of billions of stars in one galaxy, the Milky Way Galaxy, and there are billions of galaxies in the universe. The possibility that there are other living things in this vast universe is evident, and some of these living things may be more advanced than we are. As a consequence, man has difficulty in claiming stature on the basis of any special cosmic position or advantage.

In a modern approach to reality, youngsters can see that man achieves stature through his accomplishments. The universe is vast: this means that there are practically no limits to man's potential explorations. Gaining more knowledge about the universe is a challenge to everyone, especially the children of today. They may begin to form concepts about the universe in the elementary school, and continue to refine and extend these ideas throughout their lives.

One of the most important characteristics of the solar system is order. In their study of science, pupils sometimes come to believe that everything that they learn has to be qualified, and that nothing is "really known." Although skepticism is generally a healthy attitude, children should also realize that some things are known with considerable certitude. The movements of the moon, earth, and other planets, for example, can be predicted with such accuracy that we base our calendars and systems of keeping time upon them. As young people learn more about science and the methods of science they will begin to ask: "How well do we know?" In the study of the solar system and the universe, children encounter information and ideas that are very well known; other information and ideas are based on incomplete evidences and are admittedly tentative.

The earth and the sun. To the inhabitants of the earth the sun is the most conspicuous and important astronomical body. Most of the energy we use comes either directly or indirectly from the sun. In fact, without the energy from the sun, life as we know it would be impossible. The tremendous importance of the sun to us is the most basic understanding to be developed in this unit.

Children should learn that the sun is a star, and that the only reason it appears brighter than other stars is because it is much closer to us. The fact that the sun has been giving off energy for a long time, and that it is believed it will continue to give off energy for a long time to come, should be stressed. Some attention may be given to the kinds of energy emitted by the sun such as light, infra-red, and ultra-violet radiation.

The study of "The Earth and the Sun" should help children to explain some of their observations of the sun's apparent movements. During the day the sun can be seen, and it is light. At night the sun cannot be seen, and it is dark. Children can see the sun rise in the east in the morning, pass across the sky during the course of a day, and set in the west in the evening. They can observe the change in direction and size of shadows during the course of a day. They may also notice that the apparent path of the sun across the sky and the length of shadows change with the seasons of the year. They should be helped to go as far as they can in exploring the phenomena that they see.

Pupils may be led to consider the two possible explanations for day and night and the apparent movement of the sun across the sky: the sun moves around the earth once each day, or the earth spins on its axis once each day. With lights and a globe, each of these possibilities can be demonstrated. The pupils can discover why the rotation of the earth is the better explanation.

Whenever possible, the teaching of this unit should be based on observations that can be made by the learners. Models and demonstrations are the keys to explaining their observations. In this unit it is particularly important that pupils be led to check their explanations with those that have been developed by scientists.

Important Generalizations:

1. Without the sun there could be no life as we know it on the earth. Most of the energy that we use comes directly or indirectly from the sun.

2. The sun is a star. It has been giving off energy for a long time, and it will continue to give off energy for a long time in the future.

3. The sun shines all the time.

4. Day and night, and the apparent movement of the sun across the sky, can be explained by assuming that the earth rotates on its axis.

Key Questions:

1. Where do most of our light and heat come from?

2. How can we explain day and night? Does the sun keep on shining at night?

3. How can we explain the movement of the sun across the sky from east to west?

4. How does your shadow change during the day? How can we explain this?

5. How did the people of long ago explain the movement of the sun across the sky?

The air and the atmosphere. The planet earth is made up of three important parts or "spheres": the lithosphere (the solid part), the hydrosphere (the liquid, or water part), and the atmosphere (the gaseous part). Young children sometimes hardly recognize that the atmosphere is part of the earth. Yet the atmosphere is one of the factors that makes life possible on the earth. One of the important objectives in this unit is for pupils to learn something about the nature of the atmosphere and its relationship to the environment.

Through a variety of interesting activities pupils can discover some of the physical characteristics of air. For example, air usually is invisible. By fanning themselves, pulling a sheet of paper through the air, trapping air in a plastic bag or in a glass tumbler over water, pouring air from one tumbler to another under water, and a variety of other classic demonstrations, the learners can show that, although we cannot see air, it actually is a substance that is all around us. By observing the movement of dust particles in a beam of light, and trying to explain the spread of odors through a room, children can see that these phenomena can be explained if we assume that air is made up of particles in motion. From this they can go on to study the composition of the air.

Children can demonstrate some effects of air pressure due to the weight of air. They can show that a balloon or basketball filled with air weighs more than an empty one. The difference must be due to the weight of the air. An attempt should be made to help pupils develop a concept of the tremendous weight of the air above us. This study provides an opportunity to teach the meaning of area (e.g., square inch, square foot). The pupils know or can learn that the pressure of the atmosphere is about 15 pounds per square inch at sea level. They can begin to see how much total force is exerted by the atmosphere on a book, table top, and their own bodies. They can be led to consider why their bodies do not collapse under this great pressure.

A number of interesting effects of air pressure should be demonstrated and studied. Some of these are: the use of drinking straws, pouring from a bottle or container, the effects on the body when going up in an elevator or airplane, and vacuum cups. Improvised aneroid barometers can be made, compared with regular barometers, and used to explain how we measure air pressure.

The pupils should gain some concept of the atmosphere high above us. An approach that has often been successful is to consider the nature of the atmosphere at various altitudes man has explored. For example, what is the nature of the atmosphere at the top of the highest mountain? The height at which commercial airliners fly? The highest ascent of a balloon? The greatest height achieved by an airplane? The altitude of artificial earth satellites? Pupils should become acquainted with the characteristics of the various regions of the atmosphere: troposphere, stratosphere, and exosphere. Perhaps the most important outcome of such a study is that children learn more about characteristics of the atmosphere that make life possible on the surface of the earth. They also get a clearer picture of some of the obstacles that face man as he leaves the protection of the earth's atmosphere to explore nearby space.

Important Generalizations:

1. Air is a substance that occupies space and can be weighed.
2. Air is a mixture of particles that are constantly in motion.
3. Because of its weight, the air of the atmosphere exerts a pressure against all surfaces exposed to it.
4. The earth's atmosphere is one of the factors that make life possible on the surface of the earth.

Key Questions:

1. Is air a real substance? How do we know?
2. How can we explain the pressure exerted by the atmosphere?
3. If the atmosphere exerts such a great pressure on our bodies, what keeps our bodies from collapsing?
4. Why is the air pressure less on top of a mountain than down in a valley?
5. How is soda forced from a bottle, up through a drinking straw and into our mouths?
6. Why is it hard to pour water from a narrow-necked bottle or flask?

The sun and the planets. In this unit children should develop a better understanding of the sun, the nine planets and their satellites, and the other objects that make up the solar system. Central in the solar system is the sun. Although we believe the sun to be only a medium-size star, it is relatively near, and is the source of most of our energy. Children can begin to get some concept of the distances involved as they compare the distance from the earth to the sun (93 million miles) with the distance to the next nearest star (26 trillion miles). With many youngsters it will be possible to begin the development of the concept of the light year as a unit for measuring distances in space.

We believe that the sun is the major source of energy for the nine known planets of the solar system. Certainly we see the planets because of the sunlight that is reflected from them to us on the earth. Compared to the earth and the other planets, the sun is very large. In fact, 109 earths could be laid side by side on the diameter of the sun.

Like all the other planets the earth revolves around the sun. The time that it takes for each planet to make the trip around the sun varies with the distance of the planet from the sun. The farther away from the sun a planet is, the longer it takes for it to make a complete revolution.

The earth's seasons are primarily due to the revolution of the earth around the sun, and the fact that the earth's axis is tipped. Because the earth's axis always points in the same direction, the amount of energy received by any section of the earth's surface changes throughout the year. The earth's revolution around the sun and how this leads to a change in the amount of energy received by a given part of the earth's surface can be demonstrated to children in a classroom with a source of light and a globe.

The other eight planets of the solar system can be studied in terms of how they compare with the earth. Such factors as the following may be considered: relative size, distance from the sun, length of day and year, temperatures, atmosphere, possibility of life, and special features of each planet. Children should also be shown how they can observe the visible planets and how the planets differ from the stars.[4]

The chief satellite to be considered is the earth's satellite, the moon. A visual survey of considerable detail can be made of the moon with the aid of binoculars or a small telescope. In fact, young children have made maps of the moon that compare favorably with the maps published in textbooks. With the help of models and demonstrations, the changing phases of the moon can be analyzed, and some of the problems involved in exploring the moon can be considered.

Important Generalizations:

1. The sun is the major source of energy for all planets of the solar system.

2. The reason we receive more energy from the sun than from other stars is because the sun is much nearer.

3. The light we see from the planets is actually reflected sunlight.

4. Conditions on the other eight planets are so different from those on the earth that it is doubtful that life as we know it can exist on them.

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[4] Dates and times that various planets may be seen can be obtained from various almanacs. "Sky Reporter" in the magazine *Natural History* summarizes the visual observations that can be made during the course of a month.

5. All the planets revolve around the sun. However, the time it takes a given planet to make a trip around the sun varies with its distance from the sun.

6. The earth's seasons are due to the revolution of the earth around the sun and the tilt of the earth's axis.

7. We see the moon because of the sunlight that is reflected from it to the earth.

8. The phases of the moon are due to changes in the relative positions of sun, moon and earth, brought about by revolution of the moon around the earth.

9. Half of the moon's surface is always illuminated by sunlight. But the amount of the moon's surface that is in sunlight and that we can see changes as the moon moves around the earth.

Key Questions:

1. What is a planet? What is the difference between a star and a planet?

2. How big is the sun as compared with the earth? How far is it to the sun as compared with the distance around the earth? How far is it to the next nearest star as compared with the distance to the sun?

3. How can we explain the seasons of the year?

4. Is life as we know it possible on any of the other planets? How do we know?

5. What are conditions like on the moon? How do we know?

6. How can we explain the changes that take place in the shape of the moon?

The oceans and the hydrosphere. The hydrosphere is one of the three major regions of the earth along with the lithosphere and the atmosphere. Since the oceans cover approximately three-fourths of the earth's surface, they are an extremely important part of the environment. The study of the "Oceans and the Hydrosphere" should be correlated with the units on the "Earth's Changing Surface" and "Water and Water Supply." The emphasis here should be on some of the basic scientific generalizations that help to explain phenomena associated with the oceans.

Ocean currents are an example of a phenomenon that illustrates a basic generalization of science. There are several factors involved in ocean currents, but one of the most important is convection. When most liquids and gases are heated, they expand, and therefore their density is reduced. If a container of colored warm water is placed in an aquarium of cold water, the warm water, being lighter than the cold, rises to the top of the aquarium. In the same way, the water in the ocean that is heated will rise to the top. This is one of the factors that contributes to the existence of currents. Many kinds of materials are dissolved in the waters of the oceans. In addition to salt, ocean water contains such chemicals as potassium, bromine, iodine, gold, silver, and magnesium. Children can study the process by which materials are dissolved in water. They can determine the comparative solubility of various materials, and study the relationship between solubility and temperature. They can evaporate water (if possible, sea water) to see what kinds of materials remain after the water is removed.

Since fish and other water animals depend on the air dissolved in the water for their oxygen, the amount of air dissolved in water is a crucial factor. By heating water in a beaker, children can see that air is forced out of the water as the temperature is raised. They can relate these observations to information concerning the location of the important fishing areas in the world's oceans.

Some consideration should be given to the various kinds of life to be found in the oceans. Children can study the ways that sea animals get the oxygen they need for life. An important factor here is the relationship between size and surface area of animals. Since many simple animals that live in water get their oxygen by absorbing it through the outer surface of their bodies, it is important that they have relatively large surface areas. A reason why many organisms that live in the sea are small is that small animals have more surface area in relationship to their body size. Children may also consider some of the advantages and disadvantages of life in a water environment, and some of the reasons for believing that life originated in the oceans.

The seashore is an interesting place to study living things. Many organisms that live at the edge of the sea are able to exist both in and out of water. They must withstand the lashing of the waves, icy winds of winter, and the dryness of the beach in torrid summer. In regions where children can visit the seashore, they should be encouraged to study the adaptations of the plants and animals that survive in this type of habitat.

Materials settle out of the waters of the ocean by the process of sedimentation. Pupils can study this phenomenon as they mix soil and water in glass jars in their classroom. They can see which kinds of particles settle out first, and how layers of sediment are formed at the bottom of the water. They should also learn the relationship between the nature of the sediment and surface of the soil on the continents. From this they should gain some understanding of how part of the history of the earth can be determined by studying layers of sedimentary rocks.

The study of the oceans is important everywhere, even in communities thousands of miles from the sea. In schools near the shore, youngsters should work with samples of ocean water and make firsthand observations. Farther inland, similar studies sometimes can be made along the shores of lakes. The demonstrations of many of the important generalizations involved can be carried out in any classroom.

Important Generalizations:

1. When most liquids and gases are heated, they expand and become less dense.

2. In general, more of a solid will go into solution as the temperature of a liquid is raised.

3. More of a gas such as air will stay in solution in cold water than in warm water.

4. Most animals that live in water get the oxygen they need from air that is dissolved in the water.

5. A small living thing has more surface area for its size than a large one has.

6. In a body of water pressure increases with depth.

7. Plants and animals that live at the water's edge often must be adapted to live both in and out of water.

8. Large, heavy particles will settle out of water faster than small, light particles.

9. By studying the layers of sediment formed under the oceans, a great deal can be learned about conditions on the earth when the soil and sand were washed off the land into the sea.

Key Questions:

1. Why would the study of the oceans be important to someone living far from the sea?

2. Why are more fish and other organisms found in some parts of the ocean than in others?

3. Why do the various ocean currents exist?

4. What would happen to an animal such as the whale if it should be cast up on dry land? Could it breathe? Could it continue to live?

5. If traces or remains of animals that live in the sea are found in rocks far inland, how and where were these rocks formed?

6. Gold and other very valuable materials are found in ocean water. What prevents us from getting some of these materials for our use?

Space exploration. This topic undoubtedly is one of the most exciting and challenging areas of science for most children. A new world of exploration is being opened up to man, and children want to take part in it. They want to know more about the efforts that are being made to explore space, and they are eager to learn about some of the tools that are used in space exploration.

Children should become familiar with many of the ways in which we study objects in space. Often when we mention space exploration we think only of the glamorous space probes and earth satellites. However, we have obtained more information about outer space through the use of telescopes, radiotelescopes and various means of analyzing light from the sun and stars than we have from space vehicles.

With telescopes we are able to gather in the light that comes to us from the sun and stars and is reflected to us by the moon and planets. Children can use lenses to make simple telescopes. They should also learn how a reflecting telescope works. With relatively simple telescopes, however, they can study the surface of the moon, see some of the differences between various stars, examine the visible planets and, perhaps, duplicate Galileo's feat of observing the moons of Jupiter. Such exciting experiences early in life can open up a field of exploration that children can take part in for a lifetime.

By this time youngsters should have some understanding of the electromagnetic spectrum. It is important to stress that visible light occupies only a narrow band of that spectrum, and that there are other kinds of radiation reaching us from space. Radio waves are one kind of radiation, and radiotelescopes are designed to intercept radio waves in much the same way that optical telescopes intercept light waves. Through analysis of radio waves, scientists are able to get information about objects and regions in space that cannot be seen. With children it is particularly important to stress the ways in which scientists get data about objects far out in space.

Much of what we know about outer space has come from the analysis of the light that reaches us. Pupils can use prisms to project the spectrum of sunlight. They can also study the light given off when salt, copper, and other substances are placed in a flame. From the results they can see that various substances give off a characteristic kind of light. By analyzing the light from the sun and stars, something can be learned of the kinds of materials that are present there. The analysis of the light that reaches us from outer space has been one of our most effective ways of obtaining data.

Earth satellites have enabled us to gain a great deal of information about the upper reaches of the atmosphere and nearby space. Belts of radiation have been discovered, the exact shape of the earth has been studied, and a great deal has been learned about the weather and climates of the earth. Children should have a chance to find out how such information is obtained through the use of earth satellites.

Youngsters in the intermediate grades can begin to develop an understanding of the physical principles involved in placing satellites in orbit and sending space vehicles out into space. Some concept of orbital and escape velocities should be developed, as well as some understanding of such basic forces as gravitation, inertia, and the action-reaction principle by which rockets operate. In their study of this unit, pupils should get a clearer picture of the fascinating world of outer space, and in the process they may gain better understanding of some of the basic principles of science.

Important Generalizations:

1. With lenses and mirrors we are able to gather and concentrate light that comes to us from space. This makes it possible for us to study objects and regions in space that are invisible to the unaided eye.
2. With radiotelescopes, invisible radiation that comes to us from outer space can be analyzed.
3. When heated, substances give off characteristic types of light.
4. By analyzing the spectra of light given off by the sun and stars a great deal can be learned about their composition.
5. There is a force of attraction, called the gravitational force, between all matter in the universe.
6. A body at rest will tend to remain at rest, and a body in motion will tend to remain in motion at a constant velocity and in a straight line, unless acted upon by some outside force.
7. For every action there is an equal and opposite reaction.

Key Questions:

1. What are some of the ways we can find out about outer space?

2. How does the telescope work? The radiotelescope?
3. How is the light that comes to us from the sun and stars analyzed?
4. What keeps an earth satellite from falling down?
5. What is meant by orbital velocity? Escape velocity?
6. How do we get information back from an earth satellite?
7. What makes a rocket move?

The Milky Way and beyond. Most individuals want to achieve for themselves a picture of the universe in which they live. One of the functions of elementary school science is to help everyone make progress toward this goal, consistent with the most reliable information and theories that we have.

Information and theories about the universe are sometimes difficult to understand because they are foreign to our everyday experiences. One of the most effective ways to explain these theories is through the use of demonstrations and analogies employing materials and phenomena that are common in the children's environment. For example, the classic way of explaining how all galaxies can be rushing away from each other in an expanding universe is to represent the galaxies by marks on the surface of a balloon. As the balloon is inflated, all the marks move away from all other marks. In a somewhat similar way, all the galaxies in the universe appear to be moving away from all other galaxies. One of the important functions of the teacher is to explain. To be an effective explainer in this area of science requires a good deal of insight and ingenuity.

Perhaps the best way to help children develop a concept of the universe is to picture the universe from our position here on the earth. We live on a medium-size planet that is one of nine known planets that revolve around the sun. The sun is a star. It is one of perhaps 10 billion stars in a large group called the Milky Way Galaxy. Almost all the stars we see at night are members of the Milky Way Galaxy. The Milky Way Galaxy is one of billions of galaxies that make up the universe. This is a very brief view of the nature of the universe in which we live.

The universe is vast, and it is difficult for any of us, including the children we teach, to develop an adequate concept of this vastness. Pupils should learn to use the term light year as a unit of measurement in space. An attempt should be made to develop a concept of the distance denoted by a light year. The range of the 200-inch telescope on Mt. Palomar is about two billion light years, and certainly the universe extends beyond this range. Children can compare these distances with the longest journeys made by space vehicles. Such considerations may help them develop some appreciation of the vast reaches of outer space.

The universe is very old. According to one theory, the age of the universe is from 10 to 13 billion years. According to another theory, the universe had no beginning and has always been in existence. In any case, in their study of the universe, children are dealing with great spans of time. To a twelve-year-old child, six years is half a lifetime. However, some of the light that is gathered in by the 200-inch telescope began its journey two billion years ago. Probably none of us can develop an adequate concept of this figure by comparing it with spans of time within our own experiences. It only takes on meaning as the solar system, the Milky Way Galaxy, and other aspects of the universe are studied.

"Is there life anywhere else in the universe?" This is a perennial, but always fascinating, question certain to be raised by curious youngsters. Two complementary approaches are suggested in responding to this question. First, children may be encouraged to consider the various factors of temperature, pressure, oxygen supply, food, protection from harmful radiation, and water supply that make life possible on the earth. They may also be led to question whether life could exist under radically different environmental conditions; for instance, in an atmosphere composed largely of methane. This approach can lead them to an appreciation of the unusual combinations of conditions that are required by familiar organisms. In the second approach, children consider the vastness of the universe and the possibility that some of the billions of stars in the universe have systems of planets somewhat like our own solar family. This approach can lead to an appreciation of the possibility that there may be other planetary systems far out in space, and that some planets of such systems may have physical environments not unlike that of our earth. After examining the question through these two approaches, teacher and pupils will probably say in all humility, "We don't know as yet."

The modern view of the universe is no doubt difficult to conceptualize, but it is challenging to the imagination and men have seldom abandoned areas of investigation because they called for conceptualizations that seemed foreign to everyday experiences. Instead, these areas are viewed as providing rare opportunities. Certainly, this is the way most children approach the study of "The Milky Way and Beyond."

Important Generalizations:

1. The earth is one of nine known planets that revolve around the sun.

2. The sun is a star. There are billions of other stars in the universe. Some of these stars may have planets revolving around them.

3. The light and other energy from the sun and other stars is the result of a reaction somewhat like the reaction that takes place when a hydrogen bomb explodes.

4. The sun is one of billions of stars in the Milky Way Galaxy.

5. There are billions of galaxies in the universe somewhat like the Milky Way Galaxy, each containing billions of stars.

6. The universe is vast. It stretches out beyond the two billion light year range of our largest telescope.

7. The universe is very old. According to one theory the universe is from 10 to 13 billion years old. According to another theory, the universe had no beginning and has always been in existence.

8. The distances space vehicles have traveled are not very great when compared with the distances within the Milky Way Galaxy and the distances between galaxies.

Key Questions:

1. How big is our earth in comparison with other objects we can see in the sky?
2. Where is the earth located in the universe?
3. How big is the universe?
4. How old is the universe?
5. How many stars are there in the Milky Way Galaxy? How many galaxies are there in the universe?
6. Will space ships from earth ever be able to approach other stars in our galaxy? Will they ever be able to reach other galaxies?
7. How do we study the universe in which we live?

MACHINES, MATERIALS, AND ENERGY

In this area of science children learn how we live with matter and energy. *Matter* is the material around us; it is the "stuff" of the universe. Matter is so common even youngsters take it for granted, yet there is much about it that we do not understand. By guided observation and elementary experimentation, pupils can gain a more refined understanding of the nature of matter, and the conditions that lead to changes in matter.

Energy is the capacity to do work; i.e., to move some matter through a distance. Again, many different kinds of energy are commonplace in the experiences of children, and they are utilizing some kind of energy at all times, often without being aware of it. But there is much more to be learned about how energy is utilized. As to the nature of energy, the questions may be simple, but the implications are profound. In this area of study the pupils learn more about the various forms of energy; the various sources of energy; how energy can be changed from one form to another; and some of the basic scientific principles that guide us as we utilize energy.

Machines are contrivances that help us do work. In some way energy must be supplied to a machine, and the machine then uses the energy to move matter through a distance. The moving of an object through a distance is work. Some machines, such as the lever, inclined plane, and pulley, are "simple." Other machines, such as the automobile engine and the rocket engine, are obviously complex. Through a study of simple machines, children can learn the basic principles that relate to the operation of all machines. When they are familiar with the principles they can better understand some of the more complex machines.

We use our understandings of matter and energy to provide ourselves with the things we need and want. The application of the scientific principles involved to improve our material circumstances is often called *technology*. In the study of "Machines, Materials, and Energy" there are many opportunities to develop understandings of the important and intricate interrelationships between science and technology.

Simple machines. In the elementary school a simple machine is often defined as "a device that makes work easier." The simple machines are the inclined plane, lever, wheel and axle, and pulleys. In working with machines, we deal with such important forces as friction, gravity, and inertia. It may be observed parenthetically that "simple machines" is a somewhat misleading designation inasmuch as the principles used to explain them are anything but simple.

Young people should have experiences in working with simple machines. They should lift objects with and without the use of machines, employ machines to do various kinds of work, think through the advantages and disadvantages of different kinds of machines, and arrange simple machines in various combinations to make more complex machines. These are the kinds of experiences through which children in the primary grades can profit a great deal.

Important Generalizations:

1. Machines can be used to increase the amount of force that we can apply.

2. Machines can be used to change the direction in which we apply force.

3. We always have to put more energy into a machine than the work that we get from it.

4. Simple machines can be combined to make more complicated machines.

Key Questions:

1. What are some ways we can lift very heavy things?

2. What kinds of simple machines are found in the following tools: knife, scissors, hammer, automobile jack, wood screw, Venetian blinds, electric light switch, and a nutcracker?

3. Is it possible to build a machine that once started will keep going forever? Why, or why not?

Heat and temperature. Heat is a very important form of energy. We use heat to keep our houses warm, to provide the energy for most of our engines, and to make changes in our environment. Both plants and animals require some energy in the form of heat in order to remain alive.

Other forms of energy are often converted to heat. When we burn a fuel, we are converting chemical energy to heat. When a box is dragged along the ground, some mechanical energy is being converted to heat due to friction. Even when electricity flows through a wire, some of the electrical energy is converted to heat. It is important for children to learn about the relationship between heat and other forms of energy.

The application or withdrawal of heat brings about important changes in the environment. When enough heat is applied to solids they melt, and when more heat is applied they change to gases. When heat is withdrawn gases change to liquids, and then to solids. Chemical reactions are usually speeded up with the application of heat.

All of us are aware that objects may be heated by conduction, convection, and radiation. In conduction, energy is transferred as molecules of a substance collide. This is the way heat energy is transferred through the walls of a stove, along a bar of metal, or through a pane of glass. In convection, the substance that is heated actually moves. The air over a radiator, for example, expands as it is heated and moves throughout the room. In the case of radiation, warm objects emit infra-red rays that will heat other objects in their paths.

It is important to clarify the relationship between heat and temperature. While heat is a form of energy, temperature is a measure of relative hotness or coldness. Many young children are ready to use thermometers to get a more precise determination of temperature. For some of them, this will be their first contact with the quantitative aspects of science. Some pupils may be ready for the concept that temperature is a measure of the relative rate of activity of the molecules in a substance. A number of simple demonstrations can be used in explaining this concept.

Youngsters should have many firsthand experiences with heat and temperature. They should have a chance to see how common forms of energy are converted to heat energy, and study the effects of heating and cooling various substances. They can learn about methods of heat transfer. Certainly they should have a chance to determine temperatures and changes in temperatures.

Important Generalizations:

1. Heat is a form of energy, while temperature is a measure of how hot or cold a substance is.
2. Many other forms of energy, such as mechanical, chemical, and electrical energy can be converted to heat energy. In turn, heat energy can be converted into these other forms of energy.
3. Objects can be heated by conduction, convection, or radiation.
4. Heat energy flows from the hotter place to the colder.
5. The application or withdrawal of heat energy results in changes in the environment.

Key Questions:

1. What is the difference between heat and temperature?
2. What happens to various kinds of materials when they are heated? When they are cooled?

3. What are some ways that heat is transferred within the classroom?

4. What makes a substance hot? Cold?

5. What are some ways in which other forms of energy are changed to heat energy within your school building?

Energy and energy sources. Energy is the capacity to do work. In this case, the term "work" is used in its physical sense; i.e., work is force acting through a distance. For any activity to take place, energy in some form or other is needed.

In our learning experiences we deal with two kinds of energy: potential energy, and kinetic energy. Potential energy is energy that some object has because of its position or condition. Water behind a dam has potential energy because it is in a position from which it can fall. Coal has potential energy because of the arrangement of the electrons in the molecules of coal. Kinetic energy is the energy that an object has because of its motion. A rolling automobile has kinetic energy because of its motion, as does the water that is falling down a penstock below a dam.

Children also deal with various forms of energy: chemical energy when they burn a candle, electrical energy when they wire an electric bell, light energy as they deal with lenses and mirrors, heat energy when they boil water, sound energy as they talk, and mechanical energy as they pedal a velocipede. They study the transformation of energy from one form to another. For example, heat energy can be transformed to electrical energy, and electrical energy can be converted to almost any of the other forms of energy.

It is important to give some consideration to various sources of energy. The sun is the source of a great deal of the energy that we use. Children can be helped to gain an understanding of how the electrical energy generated at a hydroelectric plant and the energy in coal and oil can be traced back to the sun. They should also begin to become acquainted with such sources of energy as nuclear energy and tides, and to gain an appreciation of the importance of conserving energy resources.

Important Generalizations:

1. There are various forms of energy, and energy can be transformed from one form to another.

2. In many energy transformations some heat is generated.

3. Some of our energy resources are available in limited amounts, and should be conserved.

4. Under ordinary circumstances energy can be neither created nor destroyed.

5. Energy can be changed to matter and matter to energy.

Key Questions:

1. What are ways that energy can be transformed from one form to another?

2. What happens to energy when work is done?

3. Where does the energy used by your body come from?

4. If energy can neither be created nor destroyed, why is it important to conserve energy resources such as coal and oil?

Water and water supply. Because of its physical characteristics, water is one of the most important materials in our environment. Many substances, such as soil minerals and foods dissolve readily in water. This makes water essential to both plants and animals. Water is a relatively heavy substance. It is because of this weight that a great deal of energy is released when water falls, and that heavy objects such as ships can float in water. Also, water wets many different kinds of substances, and therefore is useful in cleaning. One of the most important facts about water is that, although many regions do not have enough water, it is one of the abundant substances on the surface of the earth. In fact, about three fourths of the earth's surface is covered with water. Through a series of relatively simple investigations, children can study the various physical characteristics of water that relate to its uses.

The human body can survive for only a few days without water intake. However, the water must be safe for drinking. Children should gain some concept of how water is contaminated, and how it can be made potable again. Water is needed in industry to clean various materials, to float materials such as wood pulp through a manufacturing plant, to transfer heat energy, to remove wastes, and as an actual raw material in manufacturing. Youngsters can find out how water is used by industries in their community. One of the largest uses of water is for irrigation. The problems involved in irrigation should be understood by the children. Of course, water is also involved in transportation, and in the generation of electricity. The use of water for recreation is often of particular interest to the children.

How do the people in a community obtain the water they need? The rural dweller probably has a well. What is the source of the water that is tapped by a well? What happens when a well goes dry? How is water in a well brought to the surface? How can wells be protected against contamination? In urban areas water is often obtained from rivers or reservoirs. How is the water for a city collected? How is the water brought to homes and factories? How is the water protected against contamination?

Many of the materials from the environment that we use are involved in cycles. One of the most important of these cycles is the water cycle. Water is often misused but never lost. All water is in some stage of the water cycle. However, we can only use the water that is in one stage of this cycle. Children should gain an understanding of the meaning of water conservation in terms of the water cycle. Through the study of the water cycle they will be better able to understand other important cycles in the environment, such as the oxygen-carbon dioxide cycle and the nitrogen cycle.

Important Generalizations:

1. Because of its physical properties, water is essential for life.
2. Water can exist as a solid, liquid, and as a gas at temperatures that are common in the environment.
3. Many substances dissolve in water.
4. The water we use is in some stage of the water cycle. We

usually use water sometime after it falls as rain, and before it flows back into the oceans.

Key Questions:

1. Where is water found?
2. What are some important properties of water?
3. What happens to the water that goes down the drain?
4. How do we get our water?
5. How is water made safe for drinking?

Simple electronics. Electronics is the study of various phenomena associated with electrons. Such important devices as the telephone, radio, television, light meters, record players, X-ray machines, and radar are related to the study of electronics.

An electric current is believed to be a flow of electrons through a conductor such as a copper wire. When these electrons flow through a conductor, such as the filament in a vacuum tube, electrons are given off. These electrons can be collected again on a metal plate in the vacuum tube. The flow of electrons from the filament to the plate can be controlled by changing the electrical charge between the filament and the plate. This is one of the basic operations in electronics.

Children can work with some of the simpler electronic devices. They can see the effects of the flow of electrons through the filament of an electric light bulb. They can study the construction of vacuum tubes and learn how they operate. The building and study of simple crystal radio sets can be one of the most challenging experiences the youngsters have in elementary school science. After the crystal set, one- and two-tube sets are not beyond their ken, and they can gain some understanding of the basic principles relating to the operation of record players, radios, and television sets.

Important Generalizations:

1. Some chemical elements give off electrons in the presence of light.

2. Electrons are attracted to a positively charged object, and repelled by a negatively charged one.

3. Electronic devices such as vacuum tubes and transistors can be used to amplify weak signals.

4. Signals in the form of light, sound, pressure, and temperature can be impressed upon a stream of electrons. The flow of electrons can be used to produce light, sound, pressure, and temperature signals again.

5. The movement of electrons can be generated by the addition of energy in such forms as heat and light.

Key Questions:

1. How does the photoelectric cell work?
2. How can electrons be made to flow from a wire?
3. How can the flow of electrons be controlled? How can a vacuum tube be used to amplify a signal?
4. How does a crystal radio set operate?
5. How does a one-tube radio set operate?
6. How is a transistor constructed? How does it operate?
7. What are the basic principles involved in the operation of a television set?

Flight in air and space. For flight through air and space a force (lift) must be exerted which is greater than the gravitational force that is acting upon the aircraft or spaceship. The first aircraft were lighter than air, and floated in air somewhat like a cork floats in water. Heavier-than-air aircraft are lifted by the effect of the stream of air that passes over the top of the curved wing surfaces. Spaceships are propelled away from the earth by rocket engines.

Children can study how objects lighter than air are lifted. Balloons filled with hydrogen or helium will float up into the atmosphere, as will soap bubbles filled with a light gas. They can compare this with the floating of ships in water. The use of Archimedes' principle may be extended to explain the floating of objects in a gas as well as in a liquid.

The faster a fluid such as water or air is moving the less is the lateral pressure. This is known as the Bernoulli effect, and is used to explain the lifting of aircraft that are heavier than air. The Bernoulli effect can be illustrated in terms of such commonplace observations as the tendency of shower curtains to move in toward the spray of water, the lifting of a sheet of paper when you blow across it, and the rising of the liquid in a flysprayer or atomizer as a stream of air is blown across the open end of the tube. Where the fluid is moving the pressure around it is decreased. For example, the pressure on the side of the shower curtain next to the stream of water is reduced, while the pressure on the other side of the shower curtain remains the same. Therefore, the shower curtain is pushed inward toward the stream of water. Because the upper surface of the airplane wing is curved, air moves across the upper surface of the wing faster than across the lower surface. There is therefore less pressure on top of the wing than on the bottom and the aircraft is lifted.

For every action there is an equal and opposite reaction. When an inflated toy balloon is released, air rushes out the opening in the balloon. For this action there is a reaction which pushes the balloon forward. This principle is used to explain jet engines and rocket engines which propel jet planes and space vehicles.

Children can be helped to analyze the forces acting upon aircraft such as gravity, lift, drag, and thrust. From this analysis, they can gain an understanding of what happens when all these forces are in balance, and what happens when they are not in balance. They will see that when the forces acting on an object are not in balance, the object will be accelerated. This is one of the most important understandings in science.

Important Generalizations:

1. An object in a fluid such as air or water will be lifted by a force equal to the weight of the fluid it displaces.

2. When the speed or flow of a liquid such as air or water increases, the lateral pressure of the fluid decreases.

3. Because of the curve of the upper surface of an airplane

wing, air flows over the top surface faster than over the lower surface. This makes the pressure on the top surface of the wing less than that on the bottom.

4. For every action there is an equal and opposite reaction.
5. An object will be accelerated when the force in one direction is greater than the force in the opposite direction.

Key Questions:

1. What makes it possible for birds to fly while man cannot?
2. How is an airplane lifted from the ground?
3. How is the airplane controlled in flight?
4. What effect does the shape of a plane have on its flight?
5. How do jet engines and rocket engines work?
6. What is orbital velocity? Escape velocity?
7. What are some of the problems that have to be met for flight in space?

THE PHYSICAL ENVIRONMENT

In the study of the physical environment, some of the basic forces and forms of energy are considered. Children study and use magnetic and electric forces. They have some experiences with chemical reactions, particularly the reactions that take place in burning. Sound and light—two of the forms of energy through which we learn about our environment—are studied.

In this area pupils also begin to get an understanding of the nature of matter. They learn about the three states of matter, and how matter can be changed from one state to another. Chemical elements and how they combine to form compounds are also studied, and pupils discover the differences between mixtures and solutions. Through various science activities they investigate how solids go into solution, and how substances crystallize out of solution. Obviously, these are basic processes in science, and it is essential that children begin to form concepts about them.

A major goal is to have the pupils learn to interpret events that occur in the physical environment. To the ignorant and superstitious, phenomena such as lightning and thunder, magnetic attraction, electrostatic sparking, refraction, and echoes may seem to be magical—things to be feared and certainly not understood. Comprehension of the physical forces at work in these phenomena will allay fears, and lead pupils to search for natural, physical causes for events.

We need to learn how to use physical forces. Even young children use magnetism and electricity, and everyone, of course, uses light and sound. Many children's toys can be employed to illustrate ways in which magnetism, electricity, inertia, friction, and gravity can be used. From such experiences learners can gain an understanding of some of the basic generalizations of science. These basic generalizations are among the greatest intellectual achievements of mankind. To learn how they have been developed, to read something about the lives of the great scientists who have made outstanding contributions, and to become acquainted with some of the great experiments and investigations that have been carried out, is to gain a better understanding of the scientific enterprise.

In their study of the physical environment, it is essential that pupils have a wide variety of experiences in handling science materials and equipment. Primary-grade pupils should learn about magnetism through working with magnets. Later they should have a chance to handle such materials and equipment as candles, burners, hot plates, tuning forks, cameras, dry cells, wire, bells, flashlights, and harmless chemicals. As a result of these firsthand experiences they will acquire skills that will be useful to them throughout their lives.

Study of magnets. The study of magnetism introduces children to phenomena in which the application of a force cannot be seen. We cannot see the force of attraction that moves a paper clip toward a magnet. Young children will not be able to delve far into the explanations of why some substances are magnetic. However, through a wide variety of activities, the pupils can learn a great deal about the nature of magnetic phenomena, and how magnetism is used in toys and such household devices as a can opener and a reminder board. Magnetism can cease to be a mysterious force, and become something to be understood and used.

The teacher should suggest such activities as finding out what kinds of materials are magnetic, where on the magnet the force of attraction is greatest, kinds of materials magnets will attract through, what happens when two magnets are brought near each other, and how permanent magnets can be made. Every child in a classroom should have a chance to use magnets in such activities.

Important Generalizations:

1. Some materials are attracted to magnets while others are not. Iron and substances that contain iron are among the materials that are attracted to a magnet.
2. The attraction of a magnet is greatest at the poles. The poles are usually located at the ends of magnets.
3. Magnets will attract through most materials except those that have iron in them.
4. Unlike poles of magnets will be attracted to each other. Like poles will be repelled.
5. Magnets can be made by rubbing pieces of iron and steel with a magnet.
6. Electricity can be used to make magnets.
7. A magnet that is free to turn can be used to indicate the direction of north.

Key Questions:

1. What are some differences between the force of magnetism and some other forces?
2. What kinds of things can be picked up by magnets?
3. What happens when magnets that are free to swing are brought near each other?
4. What kinds of substances will magnets attract through?
5. On what part of a magnet is the force of attraction greatest?

6. How can we use magnets to find our way?
7. How can we make a magnet?

Fire and fire prevention. There are two major objectives in this unit: (1) to gain some understanding of what happens when something burns; and (2) to learn how to control and use fire safely. Burning is one of our most common chemical reactions, and by studying the process pupils can develop concepts about the nature of chemical reactions. Even young children should learn how to control and use fire, and certainly they should learn how to prevent and put out fires.

Often the most effective approach to teaching young children in this area is through teacher demonstrations. Many of the key ideas related to burning can be investigated using a candle. Later, the teacher may wish to show how the burning of a candle is similar to the burning of gas in a stove, and the burning of coal, wood, or other fuels. After the teacher has demonstrated many of the important generalizations related to burning, children, with careful supervision, may be given a chance to carry out some of the demonstrations with a candle.

It is important that pupils learn to control and use fire safely early in life. They will use fire in the home, and at camp, and may encounter at any time emergencies where a knowledge of fire and how to control it can save lives and property. Youngsters can safely learn such things, as well as the basic science involved, under the supervision and guidance of a competent teacher.

The pupils can find out what is needed for burning. By placing a glass jar over a burning candle, they can show that a candle will go out if it does not have access to air. By cutting the wick of a burning candle with a scissors, they can show that fuel is needed for burning. If both air and a candle are available, there will still be no fire unless a lighted match is brought near the wick of the candle to raise its temperature to kindling point. Air (oxygen), fuel, and kindling temperature are the basic requirements for burning.

Fires can be extinguished by removing one of the requirements for burning. When we throw water on a flame we momentarily deny the flame access to air and lower the temperature of the material below kindling point. Children should learn the different ways of stopping fires such as smothering with a blanket or sand, and removing the wood, coal, clothing, or other fuel.

Burning is a chemical reaction, and in chemical reactions new products are formed. Youngsters can find three products that are produced when a candle burns; they are water, carbon dioxide, and carbon. If a dry glass jar is placed over a burning candle, drops of moisture can be seen to collect on the sides of the jar. If some colorless limewater is swished around in the glass jar after the candle goes out, it will change to a milky color, and this is the usual test for the presence of carbon dioxide. If a cold cup or dish is held in the candle flame, black carbon will be deposited on its surface. From such activities children can discover that new products are formed in chemical reactions, and they will have experience with some of the techniques used to detect the products of chemical reactions.

Important Generalizations:

1. Fuel, air (oxygen), and kindling temperature are needed in order that burning may take place.

2. Fires can be put out by removing one of the requirements for burning.

3. Burning is a chemical reaction, and in chemical reactions new products are formed.

Key Questions:

1. What is burning? What kinds of substances will burn?

2. What is needed in order that a substance will burn?

3. How can we use fire safely? What precautions should be taken when a substance is to be burned?

4. If a friend's clothing started to burn, what could you do to put the fire out?

5. What happens to a material when it burns? How can we find out what products are formed?

6. How do firemen put out fires? What are some ways of putting out forest fires?

Sound and music. Sound is a form of energy basic in communication. In this unit children should gain an understanding of this form of energy, how sounds are produced and transmitted, and some of the characteristics of the special sounds called music. The learning experiences should be closely correlated with the study of "Our Ears and Hearing."

Sounds are produced by the back-and-forth vibrations of substances. Children can set up vibrations in tuning forks, rubber bands, drums, tin cans, and their own vocal cords. Sometimes these vibrations can be seen or felt. If a vibrating tuning fork is dipped down into a glass of water, the effect upon the water will be clearly evident. The important point to bring out is that it is these vibrations that generate sounds.

There are many different kinds of sounds. Children can make an inventory of the sounds that they can hear in their classroom over a short period of time. They are usually amazed at the number of sounds they can hear within a period of two or three minutes. They can classify these sounds as loud or soft, and pleasant or unpleasant. Later they can try to discover what makes sounds loud or soft, and pleasant or unpleasant.

Sounds are transmitted from the sound source to the ear of the listener. Sound waves must travel through some medium. In various science activities, children can study how sounds are transmitted through substances such as air, water, wood, metal, and string. Using the "slinky," children can study how waves that vibrate back and forth in the same direction that they travel move through a substance. With these devices it is also possible to study echoes or reflections of sound waves.

Music is composed of sound waves that are pleasant to hear. Sounds of different pitch or frequencies can be produced by plucking stretched rubber bands, or by filling test tubes or bottles to different heights with water and blowing across their tops. Children can discover relationships between the tightness of the rubber band, or the depth of the water in the test tube or bottle, and the pitch or frequency of sounds that are generated. They can experiment to see what combinations of sounds are most pleasant to hear.

Important Generalizations:

1. Sounds are produced by the back-and-forth vibrations of various substances.
2. There are many different kinds of sounds. Sounds can be classified according to loudness or softness, pitch, and pleasantness or unpleasantness.
3. Some material or medium is necessary for the transmission of sound waves.
4. Sound waves vibrate back and forth as they travel through a substance.
5. Music is composed of combinations of sound waves that are pleasant to hear.

Key Questions:

1. How are the sounds that we hear produced?
2. How are the sounds we make when we speak produced?
3. How do sound waves travel from one place to another? Through what kinds of substances can sounds travel?
4. How can musical sounds be produced? How can sounds of different frequencies be produced?
5. What are echoes? Under what conditions can we hear echoes?

Light and photography. Light is another form of energy through which we receive information. Many objects such as a burning match, a glowing filament, and the hot stars give off light. The walls of our rooms, most of the objects in our environment, the people around us, the moon, and the planets reflect light to us. We probably receive more information about the universe via light energy than in any other way.

Because so much of what we know about our surroundings comes to us by way of light energy, it is especially important that pupils gain some understanding of the nature of light.

Light travels at the tremendous speed of about 186,000 miles per second. This means that events that occur here on earth are seen at practically the same time as they occur. In space, however, the distances are so great that an event that occurs on the sun will not be seen on the earth until about 8⅓ minutes later, and an event that takes place on the next nearest star will not be seen on the earth until 4 years later.

Unlike sound, no material substance is needed for the transmission of light, for light can travel through a vacuum. Light can also travel through water, air, glass, and many other substances. Practically speaking, light travels in a straight line. However, light is reflected by many different kinds of materials, and light is often bent or refracted as it passes from one material into another.

Most light is made up of several colors. White light, for example, is made up of the various colors of the rainbow. With a prism, sunlight can be separated into a spectrum containing these color bands. Various objects will reflect only parts of the spectrum. An object that reflects only the red part of the spectrum will appear to us to be red. An object that reflects all the colors of the spectrum appears white, while an object that reflects no light appears to us to be black.

There are a wide variety of activities that children can undertake in their study of light. They can see that light travels faster than sound; e.g., we see a fast flying jet plane ahead of where the sound appears to be coming from, and we see a baseball leaving a bat before we hear the crack of the ball meeting the bat. Different kinds of substances can be classified as transparent, translucent, or opaque in terms of what happens when a beam of light falls upon them. Pupils also can carry out a number of activities to gain a better understanding of reflection and refraction. They can analyze the spectra produced by lights from various sources, and how different colors can be mixed to produce new colors.

It is suggested that youngsters examine, study, and use cameras as a way of finding out more about light. Each child can make his own pinhole camera, and he should use the generalization that light travels in straight lines to show how the inverted image is formed on the glazed waxpaper or ground glass at the back of the camera. This can lead to a study of lenses and perhaps mirrors in more refined cameras.

Important Generalizations:

1. Light travels in a straight line.
2. Light can pass through some things and not through others. In some cases light will pass through material, but we cannot see through it.
3. Shiny, smooth surfaces reflect light. When a mirror surface is flat you see an image that is very much like the object.
4. As light passes through one substance and into another it often is refracted.
5. Light travels at the tremendous speed of about 186,000 miles per second.
6. White light can be separated into the various colors of the rainbow.
7. Objects appear colored because they either give off or reflect various parts of the spectrum.

Key Questions:

1. What are the similarities and differences between light and sound?
2. Through what kinds of substances will light pass? Through what kinds of substances can we see?
3. What is white light?
4. How can we study the nature of various kinds of light?
5. What are the things that are absolutely necessary for making a camera? How does a camera operate?
6. How can we take "good" pictures?

Electricity. Electricity is one of the basic forms of energy, and a knowledge of some of the phenomena associated with electricity is essential to an understanding of the nature of matter. This makes the study of electricity one of the most important areas in elementary school science.

Other forms of energy such as light, chemical, and mechanical energy can be transformed into electrical energy. An important advantage of energy in the form of electricity is that it can readily be changed back into these other forms of energy. Also of tremendous importance is the fact that electrical energy can be transferred from one place to another with comparative ease. Children should learn how this is done, and they should also become aware of the social significance of being able to build factories, cities, and homes at some distance from the place where the energy that they need is generated.

Comprehension of electrical forces is basic to understanding the nature of matter. How is a table top, a chalkboard, or a page in this book held together? The forces that hold matter together are primarily electrical in nature. Through relatively simple activities, children can study these electrostatic forces. They can generate electrostatic charges by rubbing such materials as rubber combs and plastic bags together, and they can develop and demonstrate the basic generalization that the objects that have like electrical charges are repelled by each other, while objects having unlike charges are attracted. In doing this they are studying one of the important aspects of matter, for we believe matter is held together by the force of attraction between unlike electrical charges.

When studying the generation of electricity, emphasis should be placed on the energy transformations that take place. Children can set up simple wet cells to convert chemical energy to electricity, magnetos or small generators to transform mechanical energy to electricity, use photographic light meters to change light energy to electricity, and employ small toy steam engines that are connected with generators to change heat energy to electricity. In this study, pupils should learn a great deal more about the nature of these various forms of energy, as well as the processes by which they are converted to electricity.

They should also learn something about how electrical energy is conducted from one place to another. They can investigate conductors and nonconductors of electricity, and discover the importance of complete circuits. Some of the characteristics of series and parallel circuits can be learned by constructing such circuits with flashlight bulbs and dry cells, and carrying out a number of simple tests of each circuit. The circuits in such devices as the flashlight can be investigated. The operation and functions of such safety devices as fuses and circuit breakers can also be studied.

When we use electricity it is converted to some other form of energy. Children should learn how such devices as the electric light bulb, hot plate, toaster, and electric motor work. In many cases they can construct and operate such devices. In addition, it is important that they analyze these devices in terms of the energy transformations that are taking place. For example, they should become aware of the energy transformations that are taking place in an electric motor, and they should compare these transformations with those that take place in a generator. In developing these ideas a teacher is bringing youngsters into contact with some of the most important understandings in science.

Electricity is sometimes called our most useful "servant," and indeed the widespread use of electricity has lightened our tasks and reduced the amount of onerous work that we have to do. However, there are dangers in the use of electricity, and one of the outcomes of the study of this unit should be a knowledge of how to use electricity safely.

Important Generalizations:

1. All matter is made up of such particles as electrons, protons, and neutrons. Electrons have a negative electrical charge, protons a positive electrical charge, and neutrons are electrically neutral.

2. If there are equal numbers of positive and negative charges

in a substance, it is neutral. If there are more positive charges than negative, the substance has a positive charge. If there are more negative charges than positive, it has a negative charge.

3. Objects having like electrical charges are repelled by each other, while objects having unlike charges are attracted.

4. An electric current is a flow of electrons.

5. Electrons can be made to flow by dipping two unlike substances such as two different metals into a chemical that reacts with at least one of the substances.

6. Electricity can be generated by moving a conductor such as a copper wire through the field of a magnet.

7. Electricity will flow readily through some substances and not through others.

8. Energy in the form of heat, light, chemical energy, and mechanical energy can be transformed into electrical energy. Electrical energy can also be transformed into these other forms of energy.

9. Electricity can be used to make a magnet.

Key Questions:

1. What do we think electricity is? How does it differ from other forms of energy?

2. Sometimes when you rub your feet on a rug and then touch some object such as a doorknob, a spark is produced. How is this spark generated?

3. What are some different ways that electricity can be generated?

4. How can electricity be conducted from one place to another?

5. How does an electric motor work? An electric light bulb? An electric bell? A hot plate? A flashlight?

6. Where does the energy that lights our homes come from?

7. How can mechanical energy be used to generate electrical energy?

8. What are some things to be careful of in the use of electricity?

The materials of the environment. Matter has been defined as "the stuff of the universe." It is what we see, feel, and touch in the environment around us. The investigation of the nature of matter, of course, can become a very profound study. Some of the youngsters in an elementary school classroom may go on to take part in such profound investigations. All of them, however, should gain a better understanding of matter.

All matter is composed of basic substances called elements. There are 92 elements that occur naturally, ranging from hydrogen to uranium. A number of others have been produced artificially. Children can think of an element as being a substance that is composed of near-identical units. Salt, for example, can be divided into the elements sodium and chlorine. Sodium and chlorine, on the other hand, cannot be divided into other substances by ordinary chemical processes, and are, therefore, elements. The pupils should have a chance to handle and study such elements as copper, aluminum, iron, zinc, and carbon.

When two or more chemical elements combine a *compound* is formed. For example, when sodium and chlorine combine, sodium chloride (salt) is the product. Sodium chloride is a compound. A compound such as sodium chloride can be separated into the elements of which it is composed. A *mixture* is made up of various substances that have not combined chemically. The substances in a mixture can be separated by physical means.

Children can carry out the classic demonstration of the difference between mixtures and compounds. If powdered sulfur and finely ground iron filings are stirred together a grayish-yellow mixture is formed. The iron can be separated from the sulfur by moving a magnet across this mixture. However, if the mixture is heated with a burner, the iron and sulfur will fuse to form the compound iron sulfide. If a magnet is moved across the iron sulfide, the iron will not be separated out. The iron and sulfur have combined chemically.

Children can be led to consider the two possibilities with regard to the nature of matter: Is matter continuous? Or, is it made up of particles? They can consider the evidence that supports our belief that all matter is made up of small particles. They should also begin to become familiar with such terms as atoms and molecules. An atom is the smallest portion of an element, and a molecule is the smallest portion of a compound. A knowledge of such nomenclature is essential to the further study of the nature of matter.

Among the many interesting activities for science pupils is the study of solutions and crystals. When sugar or salt is dissolved in water a solution is formed. We believe that the actual particles that intermingle in a solution are the atoms or molecules. For example, when sugar is dissolved in water, the sugar molecules are intermingled with the water molecules. These molecules are dispersed throughout the solution. Children may wish to take samples from various parts of the solution to see if all samples taste sweet. Varying amounts of a substance can be dissolved in a given amount of water. Pupils can try to find out how much sugar can be dissolved in a pint or quart of water. They may wish to see whether or not raising or lowering the temperature of the water will have any effect on the amount of sugar that will go into solution. To test the relationship between temperature and solubility, all other factors will have to be controlled. In doing this, the pupils may begin to form some concepts about the nature of a controlled experiment.

Materials settle out of solution in the form of crystals. Various elements and compounds have distinctive crystals. With care, children can "grow" crystals of such compounds as copper sulfate, alum, and salt. They should also examine rocks to see the distinctive crystals of various minerals.

These activities can lead into a consideration of the basic building blocks of matter, the atoms. Three constituent particles—electrons, protons, and neutrons—and some of their characteristics should be considered. Some concept of atomic structure can be developed. In the case of some sixth-grade youngsters the relationship between matter and energy can be studied. These experiences should open up a field of exploration, and provide enough understanding of the vocabulary in this area to read children's science books and understand radio and television programs that deal with the subject. All young people should have opportunities for further study of the nature of the atom and nuclear energy.

Important Generalizations:

1. All matter is made up of particles. Atoms are the basic particles of elements, and molecules are the basic particles of compounds.
2. All matter is made up of basic elements that cannot be divided by ordinary means to form other substances.
3. The various substances in a mixture can be separated by physical means. The substances in chemical compounds cannot be separated in this way.
4. When one substance is dissolved in another, the molecules of the substances are intermingled, and the molecules of each substance are dispersed throughout the solution.
5. Various elements, compounds, and minerals have distinctive crystals.

Key Questions:

1. Are the materials around us "all in one piece" or are they made up of particles? How do we know?
2. If you could divide a piece of salt into smaller and smaller pieces, what would you finally get?
3. How can you get large crystals to "grow" in a solution?
4. How can we get more of a substance to dissolve into a solution?
5. Why do we believe an atom is made up mostly of empty space, with a denser nucleus near its center?

THE BIOLOGICAL ENVIRONMENT

Living things are among the most fascinating phenomena on our planet earth. What kinds of living things can be found in our environment? What are some of the important things we should learn about them? What are some of the characteristics of living things as compared with the nonliving? What is needed by living things to live? How are living things organized? How have living things changed throughout the ages? What are some of the factors that have led to these changes? How can we effectively care for and use living things? These are some of the far-reaching questions that both children and scientists ask. Children can and should begin the study of these questions in the elementary school.

In this area of science, perhaps to a greater degree than in some others, there are broad, unifying generalizations that will be dealt with in various ways in each of the years of the elementary school. Children should have continuing opportunities to develop more refined concepts of the following generalizations:

1. There is a great variety of living things.
2. All individual living things have unique characteristics.
3. All living things have certain needs, and there is a marked similarity among the needs of various living things.
4. There are important interrelationships among living things, and between living things and their environment.
5. Living things reproduce their kind.
6. Living things tend to produce more offspring than their natural environment can support.
7. Each member of a species goes through the same general development stages as its parents.
8. Over a long period of time some kinds of living things have disappeared and new kinds have appeared. There is a natural selection of those organisms that are best adapted to survive in an environment.

The learning activities provided in this broad area of science should help pupils to use these generalizations to study, interpret, and understand the phenomena of the biological environment.

In the units of study herein suggested, children should have a variety of direct experiences with plants and animals. They should learn what various organisms need in order to survive, grow, and multiply. They usually enjoy caring for plants and animals, and the study of these organisms at first hand can be quite fruitful. They can observe the changes that take place as an organism grows, the effects of various changes in the environment, plant and animal behavior, social relationships among some animals, adaptation to the environment, and similarities and differences among species and among the organisms belonging to the same species. These activities can be carried out in the classroom with plants and animals that can be easily grown and cared for.

Children should also study living things out-of-doors in the playground, a nearby park, or a field and forest, and become aware of the biological phenomena that occur there. It is especially important that they study the interrelationships among living things, and between living things and their environment. For example, they can observe the ways in which various kinds of seeds are dispersed, and how some plants are actually dependent on animals for the dissemination of their seeds. They can also study the characteristics of the plants that live in such diverse habitats as a field, forest, bog, pond, or along the edge of a sidewalk. Interrelationships can be studied in any community, and from these studies young people should become aware of the intricate relationships between various aspects of an environment. They should be led to "see where they may have only looked before."

Just as children should take some responsibility for the plants and animals that they keep in the classroom, they should also be concerned about their own biological environment. This assumption of responsibility is basic to good conservation behavior. Such behavior necessitates thinking through the consequences of proposed actions. "If we do this, what will happen?" From the study of the interrelationships that exist in any community, children can gain some insight into the possible consequences of proposed actions. When they become concerned about such consequences, they may make wiser use of the natural resources of their environment.

Animal life. Although in the case of simple organisms it is difficult to differentiate animals from plants, children have no difficulty in deciding which of the living things that they know are animals and which are plants. If asked, "how can you tell an animal from a plant?" they will usually say "an animal can move while a plant cannot." Actually, many plants do move, but their movements are usually not as clearly evident as those of animals, and a good many of the motile plants are likely to be unknown to the pupils at this grade level. In the study of this unit pupils should become aware of more sophisticated distinctions between types of organisms.

One very important aim in this study is to help children develop a clearer concept of the great variety to be found among animals. Animals differ greatly in size—the largest known animal is the blue whale, whereas the smallest animals can only be seen with the aid of a microscope. Animals have many different kinds of body coverings—cats and dogs have hair, while the snail in the aquarium has a calcareous shell. They have different ways of moving about—birds fly through the air, while earthworms burrow through the ground. They eat different kinds of food—carnivorous animals eat meat for the most part, whereas certain small animals in the sea subsist on plankton. Animals have a wide variety of habitats—many aquatic animals live only in certain regions of the sea, while others live in deserts, prairie country, or forests. With a little assistance, pupils will be able to find many other ways that animals differ.

Many animals have conspicuous adaptations that enable them to survive and thrive in a particular habitat. The color of a snowshoe rabbit's fur, for example, changes from a tawny brown to white at about the time the ground becomes covered with snow, and this makes the animal less conspicuous. Woodchucks are able to store a large amount of body fat that can be used as an energy source when they hibernate in the winter. Many birds migrate as the seasons of the year change. All animals have some kinds of adaptations, and children can study these adaptations and their relationship to survival.

Pupils should have a chance to observe the changes that take place in animals over a period of time. This can best be done by having animals in the classroom, and one of the most useful tools for this study is the aquarium. In fact, a strong argument can be made for giving every elementary school youngster a chance to study the changes that take place in an aquarium some time during his primary school years. A periodic census may reveal changes in numbers. The effect of alterations in light and temperature may be noted. Children can also carry out elementary studies to see whether fish will learn where and when they are to be fed.

Important Generalizations:

1. Animals differ in size, body covering, ways they move, kinds of food they eat, and the kinds of habitats in which they live.
2. Animals have various adaptations that favor their survival.
3. Animals are affected by their environments.
4. All kinds of animals produce offspring. Some offspring start life looking like their parents while others do not.
5. Most animals are able to move about at some time during their life span.

Key Questions:

1. What are the differences between animals and plants?
2. What are some ways in which animals differ from one another?
3. What are some of the changes that take place in the plants and animals in an aquarium?
4. How do we use various animals to our benefit?
5. What happens to various animals when winter comes?

Plant life. As with animals, there is great variety in the Plant Kingdom. The largest land plants are the towering redwoods of the West Coast; the smallest plants can only be studied with the aid of the microscope. Although many food-making plants are green, the flowers of various types may be of almost any color. Plants that do not manufacture their own food, such as the mushrooms and various other fungi, can also have different colors.

Because of various adaptations, different kinds of plants can grow in many different habitats. These adaptations serve to secure the requirements for life even though the immediate environment may appear to be barren or precarious. For example, some plants such as the water lilies are able to live underwater because they have relatively broad leaves that rest upon the surface; around them cattails and bulrushes have long stems so that the plant roots can be anchored underwater while the upper parts of the plant are up in the air and sunlight. Cacti and other desert plants have thick, waxy stems that enable them to store water. Some kinds of lichens can eke out an existence on the forbidding surface of barren rock. Children can survey their local community to discover the range of habitats in which plants live, and study the adaptations that make it possible for them to survive.

Considerable emphasis should be accorded the interrelationships between plants and their environment. Green plants need light, water, air, and favorable temperature in order to prosper and grow. If there is a lack of one or more of these factors, certain plants will not prosper. For example, grass often does not grow beneath a large shade tree because of insufficient sunlight, and corn cannot be grown north of a certain line because the period between the last frost in the spring and the first frost in the autumn is not long enough. Under the direction of the teacher, children can study areas on their school grounds, in nearby parks and fields, and in forests to learn about the factors that make it possible for some plants to grow there while others cannot.

The processes whereby plants reproduce themselves should be studied, and pupils should have some experience in propagating plants in various ways. In field, orchard, and garden they can find examples of plants that start from "runners," bulbs, roots, cuttings, and seeds. Children also can start plants growing in their classroom. The various ways that seeds are dispersed can be observed, as well as adaptations that are related to seed dispersal.

One of the best tools for the study of growing plants and, to a certain extent of animals, is the terrarium. Terrariums can be set up to simulate conditions found in a bog, a forest, a grassland, or a desert. Using a terrarium, pupils can study how plants grow, and under what conditions different plants grow best. They can see how plants propagate themselves, and what happens to the plants that die. If there is a glass top on the terrarium, children can see a simulation of the water cycle that is somewhat like the water cycle of the environment.

The growing of potted plants and gardening also provide excellent opportunities for the study of plant life. These activities can be related to the studies of the general requirements of plants (food, light, water, air, and heat). As pupils work with different kinds of plants, they become acquainted with the special requirements of some types, and the kinds of care that will enable all plants to thrive.

Important Generalizations:

1. Plants, like other living things, have certain basic requirements such as food, light, water, air, and heat in order to live and thrive.

2. Different kinds of plants have adaptations that make it possible for them to live in a variety of habitats.

3. Plants start growing in various ways such as by the sprouting of seeds, and growth from "runners," cuttings, bulbs, and roots.

4. Various plants are excluded from certain habitats because they are unable to obtain their basic requirements in those habitats.

5. All animals and some plants are largely dependent on green plants for food.

6. Plants produce new plants of their own kind.

Key Questions:

1. In what different kinds of places can plants grow? What kinds of plants grow best in the desert? In marshes? In lakes? In fields? In forests?

2. What do plants need in order to live? How do they obtain these requirements?

3. How can new plants be produced in fields and gardens?

4. In what ways are the seeds of plants spread?

5. What kind of care do house plants need? Plants that grow in the garden?

Living things and their environments. To decide what is living and what is nonliving can be challenging, and especially so when we deal with some of the simpler organisms. An interesting way to approach the study of this unit is to have children classify various familar objects in the environment as either living or nonliving things. To add zest to future discussions and investigations make certain that objects that move, change shape and sometimes grow, such as clouds, smoke, and fire are listed in the nonliving category.

How can you tell the living from the nonliving? This question is more easily asked than answered. However, children may consider and use the following characteristics of living things. It should be added that any single characteristic may also be descriptive of some nonliving object.

1. Living things are sensitive. Plants will turn their leaves in the direction of light. Roots of plants are sensitive to gravity. The corn borer seeks out tight places where there is pressure against its body. We quickly pull our hand away from a hot stove as we react to pain.
2. Living things reproduce. An ameba reproduces by dividing into two amebae. Many plants grow from seeds. Young chicks are hatched from eggs, and in many higher animals the young are born. Although the ways that living things reproduce differ, all kinds of living things have some way of reproducing their kind.

3. Most living things need food, water, and oxygen. The food is needed for energy, growth, and bodily repair. All living things contain some water; many living things are composed largely of water. Oxygen is obtained from the air in the atmosphere or from air that is dissolved in water.
4. Most living things are capable of producing movements. This is true even of plants that remain rooted in one spot, for they react to such stimuli as light, prevailing winds, and the force of gravity.
5. Most living things grow at some time during their lives.

Children should be led to realize the difficulty of distinguishing between living things and some kinds of nonliving things. A flame, for example, displays most of the characteristics of living things that have been listed. Although they cannot have direct experiences in this area, children can consider the difficulties involved in determining whether viruses are organisms or merely active chemical substances.

Living things are dependent upon their environment for their requirements: food, oxygen, water, and energy in the form of heat and light. How do various kinds of living things get these requirements? Children can study certain types of plants and animals to see how they obtain the basic necessities for living. In doing this, a wide variety of living things existing in natural habitats should be considered. How do the algae that live on the wind-swept rocks on a hillside get the food they need? How do the fish in the ocean deeps obtain oxygen? In some deserts there is practically no rainfall; how do the plants that live in these deserts obtain water? How about the mushrooms that are grown in dark cellars; do they need light in order to live? Children can ask and study similar questions about the plants and animals they find in the immediate vicinity of the school.

When we grow living things for food, fiber, or as ornaments, we usually try to provide a favorable environment. In our gardens we destroy weeds so that carrots, beans, tomatoes and other relatively delicate plants can thrive. Some of our domesticated animals such as sheep and pet birds do not usually survive unless they are protected in a special environment. By considering what living things need from their environment, children can get a better understanding of how to provide favorable conditions for the plants and animals they wish to grow.

Important Generalizations:

1. Living things have certain characteristics. These characteristics, taken together, help us to tell living things from nonliving things.
2. In some cases it is very difficult to decide whether certain things are living or nonliving.
3. Living things get the requirements for life from their environments.
4. In our homes, fields, and gardens, we can provide special conditions that will enable certain desirable plants and animals to live and grow.

Key Questions:

1. How can we tell the living from the nonliving?
2. Although a flame has many of the characteristics of living things, what leads us to say that it is nonliving?
3. Are the viruses considered to be living or nonliving?
4. Where do plants and animals obtain the things they need to live?
5. How can we make certain that desirable plants and animals survive?

The organization of living things. Both simple and complex living things are organized to perform certain functions. One approach to this area of science is to consider what functions must be carried on in order for an organism to survive and grow. For example, what functions must the human body perform?

Children can be encouraged to list the functions that their bodies perform, such as taking in food, digestion, taking in air, breathing out used air, circulation of food and oxygen to different parts of the body, excretion of wastes, protecting the body from drying, and getting information about the environment.

The next step is to consider the parts of the body that perform these functions. Various body parts are organized into such systems as the circulatory system, nervous system, digestive system, excretory system, and respiratory system. Now they can move on to the particular organs that perform specialized tasks within these systems. The skin is the structure of their bodies that is easiest for them to examine and study. They can observe its surface to see how it acts as a covering for the body, see how perspiration serves to regulate body temperature, and study cross-sectional diagrams of the skin to see how it is organized. It may be possible for children to examine eyes, lungs, hearts, stomachs, kidneys, and other organs of butchered animals to find out how they are constructed to perform their functions.

Organs are composed of tissues, and tissues, in turn, are composed of the basic unit of living matter, the cell. Children can study plant and animal cells and tissues. In the future we hope elementary school children will have access to microscopes so that they can examine the cells in a bit of onion skin, the epithelial cells that can be scraped from the inside of the mouth, and other examples. In this way they can compare plant and animal cells, and get a better understanding of the basic building blocks that make up living matter.

Living things become more highly organized as they grow, and children can study the growth of both plants and animals. Generations of elementary school youngsters have sprouted seeds on moist blotting paper, but they should also examine the insides of seeds, study the changes that take place in the seeds as they sprout, and note the organization of the plant as it grows.

Pupils can also study the organization of animals as they grow and develop. One of the most fruitful approaches to this is to observe the progressive development of the chick embryo as hen's eggs are incubated in the classroom. For example, if one egg is opened each day until the chicks in the remaining eggs finally hatch, the evolving differentiation of tissues can be followed. Similar studies can be made of the changes that take place in frog's eggs kept in the classroom aquarium. Naturally, these studies of the development of chicks and tadpoles can be extended to include the growth and development of the tadpoles and chicks after they have hatched.

Children can also study the changes that occur in an organism upon death. What happens to the fish, snails, and plants in the aquarium when they die? What finally happens to the plants and animals in a terrarium? In a sense, upon death, the organization of a living thing breaks down. Children study the development of organization as living things are produced and grow, and the gradual disorganization of living things after death.

Important Generalizations:

1. Living things are organized in such a way that the functions necessary for life are performed.
2. Cells are the basic units of living matter.
3. Cells are organized into tissues, tissues into organs, and organs may be parts of systems that perform needed functions.
4. Complex living things develop special cells and tissues.
5. Upon death, things that were once living disintegrate and the organization breaks down.

Key Questions:

1. What changes take place in a seed when it sprouts and grows?
2. How is your body organized to perform its necessary functions?
3. In what ways are plants and animals organized differently?
4. Of what is living matter composed?
5. What happens when a living thing dies?

Adaptations of living things. An adaptation is any characteristic of a living thing that increases its chances of surviving. The adaptation may be in a form of body structure such as the long neck of the giraffe which enables it to eat the leaves of trees. Or it may be a behavior pattern such as the hibernation of ground squirrels during the cold season. The adaptation makes it more likely that the individual will survive and leave descendants, and this in turn increases the chances that the species will continue to exist. All organisms have adaptations of various types and children can investigate the living things common to their environment for examples. They will also be interested in the more unusual adaptations of certain plants and animals. In communities with access to good museums, studies can be made of the remains of species of plants and animals that have not survived, and pupils can try to determine what factors may have led to the extinction of these species.

Living things have adaptations that protect them from enemies. Plants such as thistles and cacti have sharp spines that protect them against hungry, herbivorous animals. Turtles, lobsters, and crayfish have hard shells that protect them from destruction by other species. Protective coloration causes numerous animals to blend with the environment so that it is difficult to see them. Chameleons and plaice are animals that change their colors as they move from one environment to another. Through mimicry the dead leaf butterfly and walking stick insect remain hidden to their enemies. Wasps, bumblebees and honeybees have painful stings; skunks can emit an odorous fluid. Many animals such as deer and antelope use their running speed to escape enemies.

Living things also have adaptations that enable them to get food. Many plants have widespread and deep root systems by means of which they get soil minerals and water. Some plants such as the pitcher plants and sundews are insect trappers. Spiders spin webs which help them to capture their small victims. Hummingbirds have long bills that aid them in getting nectar from flowers. The hamster has a pouch in which it can store food for future use.

Pupils can find a number of living things that have adaptations that keep them from drying out in the hot sun. The leaves of the corn plant curl when it is hot and dry so that less water will be lost from the leaf surfaces. Desert plants such as cacti have a waxy coating over their stems; many of the animals that live in the desert will retreat into the shade or into burrows during the heat of the day.

In most communities we can find living organisms that are adapted to seasonal changes. Deciduous trees lose their leaves and survive the winter in a semi-dormant state. Annual flowering plants produce seeds during the growing season, which may be short, and these plants are able to survive as species because the seeds can remain viable through the cold winter. A number of animals such as the cow, horse, dog and cat will grow thicker fur in the winter; some animals such as the weasel will undergo color changes so that their appearance blends with the surrounding environment.

As a result of their study of various adaptations, many youngsters are ready to begin to develop a concept of natural selection. They will see that living things with certain adaptations are more likely to survive than the living things that do not have such advantages. If many members of a particular species do not survive long enough to reproduce, then that kind of organism may eventually cease to exist. Natural selection is one of the most important generalizations in the biological realm. Elementary school children can begin to develop a concept of the nature of the process, and of its importance as a conceptual framework that helps us to explain the phenomena of the biological environment. Their understanding of natural selection will be refined and deepened as they continue their studies in science.

Important Generalizations:

1. Adaptations are characteristics of living things that increase their chances for survival in their environment. All living things have adaptations of some kind.
2. Some living things have adaptations that protect them from their enemies.

3. Living things have adaptations that enable them to get food.
4. Some living things have adaptations that keep them from drying out in the hot sun.
5. Some plants have adaptations that help them to get the light that they need.
6. Many living things are adapted to seasonal changes.
7. Organisms that have adaptations enabling them to live to the age at which they reproduce are more likely to survive than organisms that do not have such adaptations. A system of selection operates in nature. Well adapted organisms tend to survive; poorly adapted organisms tend to be eliminated.

Key Questions:

1. What are some ways in which plants and animals are protected against their enemies?
2. What are some of the adaptations that plants and animals have to get food?
3. How are some plants and animals protected from drying out in the hot sun?
4. What are some ways in which plants and animals are adapted to seasonal changes?
5. What are some possible explanations for the disappearance of such animals as the dinosaurs? Passenger pigeons?
6. How can we explain some of the changes that have taken place in various plants and animals over a long period of time?

Man's use of living things. To a considerable degree man is dependent on other living things for many of the necessities for life. In fact, we use materials derived from living things for the three basic essentials: food, clothing, and shelter. We are utterly dependent on other living things for food. Much of the fiber that we use to make clothing, and in many regions most of the raw materials employed to construct homes are also derived from the biological environment. Living things are also the source of much of the energy that we use to run our complex civilization. Some of the most important developments in science and technology are those that have led to new ways of utilizing living things, and to the improvement of the products made from these natural resources.

Children can study the food chains in which man participates. Inevitably, these food chains lead back to the green plants, and this shows that we and the rest of the animal kingdom as well are largely dependent on green plants for basic foods. Although we may use milk or meat from animals, the milk or meat was produced from parts of green plants eaten by the animals. Children may also analyze the foods they eat, to see which parts of plants or animals are used, and how they are processed and preserved before we eat them.

The parts of some plants such as cotton and hemp contain long fibers that can be woven into cloth. Similarly, long fibers can be obtained from the cocoons spun by silkworms and from the furry coats of such animals as sheep, goats, and camels. The processing of these fibers to make clothing involves a number of important scientific principles. The skins of such animals as pigs, cows, horses and sheep are processed into leather, and these transformations also involve a number of scientific principles.

Lumber from trees, and to a lesser extent reeds and rushes, and the skins of animals, are used to construct shelters in various parts of the world. Again, children can study how the raw materials are utilized and the various building materials that are made from them. This can lead into a study of certain qualities such as tensile strength, ability to support weight, and heat insulation that are desirable in building materials.

Living things and materials that have been formed from living things are exploited as modern sources of energy. Animals such as horses, mules, donkeys, oxen, and elephants have long been used by man to help him with his work. Today, their importance as sources of power is no doubt diminishing. The remains of prehistoric plants and animals in the form of coal and oil are probably our most important current energy sources. An examination of how we think these fuels were formed, and how they are extracted from the earth, processed, and used will demonstrate to the learner how dependent we are on organic materials for energy, and how various principles of science and technology are applied to convert such fuels into forms that can be used.

Living things also have an important aesthetic function. Gardens and lawns, forests and fields, birds, insects, and wildlife of all kinds are desirable parts of our environment. It may be possible to live without them, but they make life more satisfying. One of the hoped-for outcomes of elementary school science is that some youngsters develop satisfying hobbies and avocations involving the study and use of living things.

A certain amount of knowledge and skill is needed to care for and use living things effectively. Some people are very successful in growing plants and are said to have a "green thumb." Actually, they know much about what plants require in order to thrive, and they apply their knowledge and insights to achieve success in growing plants. Others use their knowledge of animals to raise and train them for tasks ranging from the herding of sheep to the performance of clever tricks. Projects involving the growing of plants and the care and training of animals can be significant elementary school science activities.

It is to the advantage of those who use living things to try to obtain the best possible plants and animals. One of the ways to do this is to select only superior types for breeding. However, this means that the user must be able to judge quality. For many different kinds of plants and animals sets of criteria have been developed for such purposes. Through study and practice, young people can become adept at judging quality, and therefore better able to select plants and animals for purchase and propagation.

Children should also study other ways of improving the plants and animals that we use, and begin to gain some understanding of the science of genetics. The process and advantages of developing purebred strains should be considered, and pupils may also begin to gain an understanding of hybridization. They can study and actually employ such techniques as grafting and budding, and utilize the vegetative reproduction of some plants to ensure that desirable traits are transmitted to the offspring.

In this, as in other units, concepts associated with conservation should be developed. In one sense, conservation is the wise use of natural resources. We must use living things for food, clothing, shelter, energy, and aesthetic enjoyment, but we should use these resources so that we derive maximum benefits. Of perhaps greater importance, these resources should be exploited in such a way that we are assured of their perpetuation in the future.

Important Generalizations:

1. Man is dependent on other living things for many of the necessities of life, such as food, clothing, shelter, energy, and aesthetic enjoyment.
2. We are dependent on plants and other animals for food.
3. The long fibers found in some plants and in the furs of some animals are woven into cloth and used for clothing.
4. Some plant and animal materials have the tensile strength, ability to support weight, and heat insulating qualities needed in materials used for shelter.
5. Living things and fuels formed from living things such as wood, coal and oil are very important sources of energy.
6. The care and use of living things involve a knowledge of what living things need in order to live, and the ability to make the best use of these plants and animals.
7. Through such practices as quality judging, careful selection, development of pure strains, and hybridization, the plants and animals we use can be improved.
8. Plants and animals should be used so that we derive maximum benefits, and assure adequate resources for the future.

Key Questions:

1. What are some of the different ways we use living things?
2. How do we obtain the long fibers we use to weave cloth for clothing?

3. What do we really mean when we say a person has a "green thumb"?

4. What are some interesting hobbies and avocations that involve the use of plants and animals?

5. How can we improve the plants and animals we use?

6. How can we tell a good plant or animal from a poor one?

Chapter Four

ADMINISTRATIVE ORGANIZATION

Elementary school administrators can stimulate, encourage, support, and otherwise make possible good teaching-learning in science. It is the *quality of the experiences* that children have in science that is important, and this depends on the quality of the teaching. The effectiveness of instruction, in turn, usually relates to the way the school is organized, the stimulation and encouragement given the teachers, the resources that are made available, the support given consultants and supervisors, and the intellectual climate that is developed within the school. Although good teaching sometimes can take place in spite of unsatisfactory administrative organization, it will be much better if teachers are provided with wise leadership in planning, considerate encouragement for experimentation, and adequate materials and equipment.

SCHOOL ORGANIZATION AND ELEMENTARY SCIENCE

The basic question of school organization for elementary school science is, "Who shall teach science to children in the schools, and how can their teaching be supported so that it will be most effective?" Unfortunately, there has not yet been a sufficient amount of research on this problem for a clear picture to emerge of what is most effective and desirable. The best that we can do is to describe some of the arrangements that are often found in our elementary schools, along with their advantages and disadvantages, and then suggest an approach that seems to us to have considerable promise.

One thing is certain. There is no cheap solution to the problem of good teaching. No matter which plan is used—the classroom teacher plan, the elementary science teacher plan, or the classroom teacher-science consultant plan—the quality of the resultant program will only be as good as the program that is planned, the materials and equipment that are provided and, most important, the teachers and consultants who work with the children. A classroom teacher working with too many children cannot know them as individuals. An elementary science teacher who has too many classes and classroom groups that are too large, cannot be expected to use his special information in science effectively. A classroom teacher-science consultant team cannot be expected to succeed in building a sound program if the consultant has too many classrooms with which he must work, or if the classroom teacher has so many other demands that proper attention cannot be given to instruction in science. Good teaching is expensive, but it is worth the price.

The classroom teacher teaches science. Undoubtedly, the most common arrangement for the teaching of science in elementary schools is for the classroom teacher to do the job in what is often called the self-contained classroom. The classroom teacher works with the children in all areas of the curriculum: reading, arithmetic, social studies, writing, music, art, physical education, and science. The teacher may have help from special teachers in such areas as music, art, and physical education. The teacher is usually assisted in general program planning by a supervisor, curriculum coordinator, or administrator. However, this classroom teacher has the awesome responsibility of teaching twenty to forty or more children in all areas of the curriculum, as well as being deeply concerned with the general physical, moral, and cultural development of each child.

Advantages:

1. The classroom teacher may have an opportunity to get to know each individual child well and, with this intimate knowledge, plan a program that will help each child grow and develop. This opportunity to work with a group of children over an extended period of time, and perhaps be able to plan a program that will meet individual needs is the most important advantage of this type of school organization.

2. Because the classroom teacher works with a single group of children throughout most of the school day, the teacher is able to plan comprehensive activities that will lead to growth in many areas of the curriculum. For example, the planning and writing of a class newspaper can involve significant learnings in such basic curriculum areas as language arts, science, art, social studies, and arithmetic. Furthermore, work of this kind can lead to the development of such important abilities as leadership, skill in planning, and business management.

3. Because the classroom teacher teaches most of the subjects of the curriculum, relationships among various areas of study may be emphasized. For example, the study of modern communication certainly involves the study of electricity as used in the telegraph, telephone, and radio, but it should also include the study of the social effects of modern developments in communication, and an appreciation of the aesthetic dimensions of various modes of expression. The classroom teacher is in a position to make a sensible and fruitful integration among studies in various areas of the curriculum.

4. The classroom teacher can plan the use of available time for effective learning. Instruction in a subject does not have to take place only during arbitrarily selected time intervals.

Disadvantages:

1. Since the classroom teacher has to work in all areas of the curriculum, it is difficult, if not impossible, for this teacher to

develop the high-quality experiences in all areas of the curriculum that are needed for the optimum growth and development of children. As elementary school programs begin to emphasize a "depth approach" to the study of various fields of knowledge, as recommended in this monograph for elementary school science, it will become increasingly difficult for general classroom teachers to work without help in all phases of instruction.

2. Often general classroom teachers have not had sufficient background in science to seize opportunities to use and demonstrate scientific methods of dealing with problems. For example, a teacher who has had no experience with controlled experiments cannot help children devise a controlled experiment to find an answer to a question or problem.

3. There is often a lack of provision for developing the unique talents of individual pupils. The elementary school child who has a deep interest in simple chemistry, for example, may find few resources and little help in the elementary school to develop further his special interests and talents.

An elementary science teacher teaches science. In some school systems, especially large city systems, special science teachers teach science to the pupils. In many systems this pattern is not followed in the primary grades, but is limited to the intermediate and upper grades.

Usually, science is taught for one period of forty to sixty minutes a day. For one half of the day, the children study with a general classroom teacher. For the other half day, the children are taught various subjects, including science, by teachers who have specialized in these areas. The elementary school science teacher often is a general classroom teacher who has achieved a more substantial background in science than the usual classroom teacher. This science teacher often serves as a general classroom teacher for half of the school day, and then teaches science to two or three classes during the other half of the day.

Advantages:

1. The science is taught to children by an elementary school teacher who has developed a better than average background in the subject. Because the teacher knows more science and is better acquainted with methods employed in the sciences, he can be resourceful and imaginative in developing a range of science experiences, and can help children become acquainted with the methods of science.

2. The elemetary school science teacher is able to utilize many resource materials; can improvise apparatus for effective science teaching; and knows how to employ more sophisticated scientific equipment for developing science experiences with children.

3. The various pupils of a given grade, though they are in different classes, are more likely to have common science experiences when they have the same teacher.

Disadvantages:

1. The elementary school science teacher who meets with a group of children for only one school period a day cannot gain as deep an understanding as a general classroom teacher of what individual children know and do not know, or can and cannot do. Thus, the elementary school science teacher may not be in as good a position to know what kinds of science activities are needed to promote individual growth and development. Since optimum growth and development is the aim of education, this can be a serious weakness of this kind of school organization.

2. When science and other subjects are taught in special periods there is a danger that the children will view each of the subjects as being unrelated to other areas of the curriculum. Certainly, it is difficult if not impossible for the special elementary school science teacher to develop unifying experiences in which science, mathematics, social studies, and the language and creative arts are all taught in relationship to one another.

Classroom teacher and science consultant develop a science program. In some school systems the general classroom teachers are aided by science consultants in planning the science program and developing science experiences. The classroom teachers retain their responsibility for all educational experiences of the pupils in their classes. However, they call on the science consultant for help in using science equipment and sometimes in the actual teaching.

The elementary school science consultant is someone to whom the teacher can turn for information and assistance. Some classroom teachers fear the teaching of science because of the difficult questions that children ask. With a science consultant available, the teacher can turn to him for help in dealing with the questions that require a better background in science than most classroom teachers are likely to have. The science consultant may also participate in field trips, and in the development of projects; he provides additional science experiences for the children who have special interests or aptitudes.

Because the classroom teacher has the over-all responsibility, the consultant usually contributes upon invitation to do so. On the other hand, he takes the lead in planning the over-all science program for the school, and in providing the materials, equipment, and resources that are needed to implement this program. Ideally, the classroom teachers and science consultant work together as a team in providing the best possible learning experiences in science.

Advantages:

1. This form of organization retains the major advantage of the self-contained classroom, i.e., having one teacher who knows each individual child well and is in a good position to guide the learning experiences. The chief weakness of the self-contained classroom—lack of background in the area of science—is met by having a consultant with a substantial background in science available to advise and aid the teacher.

2. There is leadership from the science consultant in developing an integrated elementary science program throughout the

school. This helps to ensure that each child has an opportunity for progressive rather than repetitive experiences in science.

3. Children with interests and aptitudes in science are given more opportunities to progress as they work and study with a person who has a good background in science and can lead and challenge them.

Disadvantages:

1. Because there are sometimes two people working with a group of children rather than one, the classroom teacher-science consultant arrangement is more expensive than the other two kinds of school organization.

2. Careful planning is needed to take optimum advantage of the talents and resources of both the classroom teacher and the consultant. The classroom teacher needs to learn how to use consultant help. The consultant must be very skilled in working with teachers.

3. There is a danger that the classroom teacher will not use the science consultant's services, or that the consultant will attempt to dominate a classroom program.

THE CLASSROOM TEACHER-SCIENCE CONSULTANT TEAM

The classroom teacher-science consultant teaching team is one of the most promising forms of school organization for the improvement of elementary school science. It is important in the elementary school to have at least one person who knows each child well. In most schools this person is the classroom teacher. After all, one of the chief functions of the teacher is to guide the individual as he learns. A child may not see much meaning in a particular science experience. The classroom teacher, however—if he is apperceptive and knows the child well—may be able to relate this science experience to past experiences. It is when such relationships are seen that children exhibit the bright gleam that comes at the moment of understanding.

The various activities in reading, writing, mathematics, science, music, art, and physical education in which children take part should be coordinated by some one person—the classroom teacher. These areas of learning are not disparate. Instead, they are related and complementary; children should learn reading and arithmetic while they are studying science, and it is also possible that they will learn considerable science while they are studying reading and arithmetic. Experiences in various areas of the curriculum should complement one another; the general classroom teacher can assist in attaining this goal.

In each area of the curriculum and most certainly in science, pupils should be stimulated and challenged to delve as deeply as they can into the various understandings. To do this in science, they need the help and guidance of someone who has a sound background in science subject matter. This is where the science consultant comes into the picture. The good general classroom teacher can guide the children through many of the standard activities in elementary school science. The classroom teacher can provide, for example, a variety of experiences with magnets, but a rich background in science is needed if the children are to begin to see the relationships between experiences with magnets and the history of science, other important fields of science, applications in technology, and new developments in science and technology.

It is also important to have someone in a school who makes it a point to keep informed of significant new developments in science and technology; reviews the many new books, films, filmstrips, and pamphlets; and has a superior knowledge of equipment and teaching aids that can be used to advantage in elementary school science. The science consultant can perform this service.

An administrative arrangement similar to the classroom teacher-science consultant plan has been tested out in a number of school systems in the past twenty-five years. Through this kind of organization the chances are improved that children will have the kinds of experiences in science that will be needed in the second half of the twentieth century.

How the classroom teacher and consultant plan and work together. The classroom teacher and science consultant are a teaching team. The science consultant works with twenty-five or more classroom teachers. His working relationships with each of these classroom teachers varies. The classroom teacher deals with the consultants or special teachers from other areas as well as science. The classroom teacher works with each of these consultants in such a way as to utilize their individual talents and resources.

Although there are many ways in which classroom teachers and science consultants can operate effectively as a team, a description of how they have worked together to develop experiences in a unit on "The Earth and Its Resources" may suggest some of the possibilities that are opened up by such a teaching relationship.

The science consultant takes the lead in developing the planned dimension of the school's science program. The planning is done by committees that represent classroom teachers, school administration, parents, the scientific community, and other interested members of the community. The science consultant, however, is the professional science educator on this team. He is familiar with courses of study that have been developed in other communities, textbook series, and the science-resource materials available. He makes certain that there is articulation between the various grades of the K–12 science program. In one actual example, the science program planning committee developed a program similar to the Science Manpower Project program, and included a unit on "The Earth and Its Resources" in the sixth grade.

The classroom teacher and the science consultant plan for the experiences the children will have in each area of science. The classroom teacher knows the children intimately; the consultant is aware of the wide range of possible experiences in each phase of science.

In the actual example previously cited the teacher and the consultant decided on the objectives for their work in this unit.

They planned for field experiences to collect samples of the rocks and minerals to be found in the local region, visits to local industry, a film on how the interior of the earth is studied, text and library reading for the class, exhibits to be borrowed from the local museum, and potential subjects for special studies and reports by groups of pupils.

The classroom teacher then guides the children's science experiences, relating them to experiences in other areas of the curriculum. The classroom teacher calls on the consultants and special teachers of the school to help make all learning experiences as meaningful as possible. In this case, the classroom teacher organized the class into a "research seminar." Small groups of children worked on selected questions in the classroom, the consultant's laboratory, the school and community libraries, and out in the field. They reported their findings to the entire class, including the teacher and science consultant.

The science consultant teaches special skills and helps with scientific equipment and materials. He should be familar with the tools, equipment and materials used in elementary science, and skilled in helping children learn how to employ them. One group of children wanted to identify the minerals found in various rocks in the community. The science consultant showed them how minerals are classified on the basis of their physical characteristics. He showed them how to check specimens for such characteristics as color, streak, hardness, and cleavage. He provided the pupils with a simple key to minerals, and demonstrated how it could be used.

The consultant is available for consultation about special problems that arise in teaching science. In a science program all problems and possibilities cannot be foreseen. In addition, there should be sufficient flexibility to take advantage of the various opportunities that arise. To do this, the classroom teacher will often have to seek the advice of the science consultant. A group of youngsters wondered whether it would be possible for them to check the rocks that they had collected in the community to see if any of them were radioactive. When the teacher discussed this with the science consultant, a Geiger counter was produced and the teacher was instructed in its use. As a result of this, the children and teacher were able to check their rock samples for radioactivity.

The science consultant works with the children who have special interests and abilities in science. In a good elementary school program there should be opportunities for such pupils to grow and develop. The science consultant can challenge and guide the science-talented children. As a result of their study of "The Earth and Its Resources," a small group of youngsters became interested in building a collection of minerals. The science consultant showed them how such a collection could be catalogued and stored. He helped them to make contact with a local rocks and minerals club, and with collectors in other parts of the country. He served as an adviser to their informal club.

The science consultant prepares learning materials that can be used by children and teachers. Sometimes, the kinds of science materials that are needed are not available from commercial sources. This is particularly true when the desired materials relate to recent developments in science. In some cases consultants prepare a monthly newsletter describing some of the latest scientific discoveries. In the school system discussed in the preceding paragraphs there was considerable interest in the modern view of the nature of the earth's interior. The science consultant reviewed articles in a number of scientific periodicals, and prepared a short paper on the earth's interior that could be read and understood by elementary school children. He supplemented this with a short list of suggestions to teachers on how children could be helped to gain an understanding of modern theories about the nature of the earth's interior.

The consultant also carries on in-service work with teachers. A good classroom teacher seeks continual growth in understanding and skill. It is especially important that the science consultant work with new teachers to acquaint them with the science program, the equipment and materials available, and the kinds of services the consultant can offer. All the sixth-grade teachers in the school described herein were interested in learning how a Geiger counter could be used to detect radioactivity in rocks. As a result, the science consultant planned an in-service session at which he discussed the nature of radioactive emanations, the physical principles involved in the operation of a Geiger counter, and how the counter could be used to detect radioactivity.

The classroom teacher and science consultant evaluate the work that has been done in science. The instruction should lead to growth on the part of children in terms of the objectives that have been established for the program. The classroom teacher, working closely with the pupils, is in the best position to observe growth on the part of individuals. The science consultant, on the other hand, has a deeper understanding of the nature of scientific activities and attitudes, and can sensitize the teacher to observe growth in terms of ability to use various methods of science, and in the development of such scientific attitudes as open-mindedness and critical-mindedness.

The classroom teacher-science consultant teaching team can provide children with a range of challenging experiences in science that can stimulate and nurture the growth of all participants. This kind of administrative organization can lead to considerable improvement in the science programs in the elementary school, and should be tested further in actual practice to reveal its various potentialities.

A CLIMATE FOR THE DEVELOPMENT OF ELEMENTARY SCIENCE

Some scientific laboratories never rise above mediocrity, while others foster creativity and achieve greatness. In a similar way, our schools can perpetuate mediocrity, or they can strive for excellence, and in so doing help children achieve experiences that will "make a difference" in their lives. Which direction will our schools take? The answer depends to a large extent upon the intellectual climate that is developed in the schools.

This intellectual climate that supports creativity and encourages excellence in teaching is somewhat like the atmosphere that envelops a school. A climate of creativity is difficult to describe, yet an experienced observer can quickly tell whether or not it exists. A satisfactory intellectual climate is difficult to establish—it can neither be legislated nor decreed—it may also be destroyed overnight by hasty, unwise actions. If a school does not have this climate, it should be fostered with all the adroitness that is at our command; if a school does have such a climate, it should be guarded and nurtured with consummate care.

The following are some administrative and organizational steps that can be taken in the effort to develop an intellectual climate of creativity and excellence:

1. Science should be recognized as an integral part of the elementary school curriculum. It is difficult to see how a community can be said to have a modern elementary school program in the mid-decades of the twentieth century if science is not so recognized. Science experiences should be expected as well as encouraged in each grade of the elementary school.

2. There should also be support for experimentation in elementary school science. Fresh ideas and new approaches make for more effective and exciting teaching. True, there are risks. The new approach may not work as well as the more traditional one, but if new approaches are not tried, ruts will harden and the program will soon stagnate.

Teachers and science consultants should have a chance to discuss the ideas they want to try out. In a sense, they need a sounding board so that they can explore their ideas and discuss their plans. This should be one of the functions of the school administrator or curriculum coordinator.

At times there may be a need for assistance in the evaluation of experiments. Standardized tests, observational forms, and consultant help in evaluation should be made available whenever they are required.

3. The study of individual children and their growth in

science should be encouraged. Through their study of science, Johnny and Jane, Sue and Sam, and all the other individual children in a class should grow in their understanding of phenomena in their environment, skill in using apparatus and equipment, ability to use some of the methods of science, ability to read and understand science books and magazines, and in critical-mindedness and open-mindedness. The relative success of science instruction depends on the quality and extent of this growth. Not only is child study an excellent approach to the evaluation of the science program, but it also helps teachers learn what each child knows, and can or cannot do. With such knowledge the teacher can do a better job of helping each pupil. Child study is one of the most important approaches to the improvement of teaching and learning.

4. Means should be provided for the exchange of ideas among teachers and science consultants. If there is to be continued improvement in program and teaching practice, opportunities have to be provided for the exchange of ideas and experiences among teachers. Some of this interchange should be among teachers in the same school building, as they face common problems and work together to improve programs. Teachers and consultants also need opportunities to compare ideas with their counterparts from other schools; this is one of the ways that new ideas and practices are introduced.

5. Teachers and science consultants should be encouraged to achieve professional growth. Teaching is a profound undertaking. It requires scholarship in various areas of human knowledge, and it requires skill and insight in working with children. A teacher can influence the total pattern of a child's life. This is a responsibility to be taken seriously and, to meet the responsibility, continued professional growth is required.

There is a continuing need for teachers to study science. Science is a dynamic subject and it is important to learn about new developments. Teachers must have opportunities to take courses in science, especially courses that are related in some way to their work in the elementary school. Reading science books, discussions with practicing scientists, participation in science conferences, and teaching science are other ways that better backgrounds in science can be developed.

Teachers should also be encouraged to improve their ways of working with children in science. Sometimes special workshops and institutes deal with science-teaching problems. In courses concerned with elementary school science, approaches to teaching science are discussed, as well as the subject matter of science in the elementary school program.

Chapter Five

MATERIALS AND FACILITIES

An educational plan is only as good as its implementation, and this certainly is true of elementary school science. For the *Modern Elementary School Science* program, science materials, equipment and facilities are essential. For too long we have been asking elementary school teachers to teach science with no facilities and few materials. Imagine a program in art or one in physical education that would start with the basic premise that all equipment must be improvised or purchased from a ten-cent store. True, much can be done with such improvised materials, but our children deserve something better. They should have the best that we can offer, and this means that they must have access to science materials, equipment, and facilities.

At the same time, there are many things commonly found around the home or around school that can be used in the science program. When a tin can is satisfactory as a container, there is no reason to purchase a two-dollar pan. If empty milk cartons can serve as receptacles for sprouting seeds, there is no reason to buy flower pots. But galvanometers and microscopes are neither free, nor common around the home, nor are they available from ten-cent stores. And such items of equipment are essential for a sound elementary school science program of the kind that has been outlined in the foregoing pages.

First, there must be a capital investment in the building plant so that the elementary school science program can be started, and then a budget for the science program as it is carried out from year to year. The capital investment and annual budget are needed to provide four kinds of facilities and materials:

1. Permanent facilities which require building construction such as areas for science work, including the provision of water, gas, and electricity.
2. Equipment of a durable nature: e.g., tools, microscopes, and meters.
3. Supplies of an expendable nature: e.g., seeds, chemicals, and test tubes.
4. Teaching aids: textbooks, encyclopedias, trade books, films, filmstrips, and periodicals.

Consideration of each of these items is important. Schools provide for them in different ways, depending on the nature of their budget systems. Some criteria for determining how these materials may be selected, and suggested lists of desirable items are provided in the following pages.

PERMANENT FACILITIES

First, there must be enough classroom space for an active learning program. Each classroom should have a place for carrying on science activities, and areas set aside for storing and distributing the equipment which is needed for science activities. The space required necessarily depends on the size of the group destined to use the classroom. If there are to be twenty-five children in each group, then there must be room for twenty-five to work in science. This is not as expensive as might appear on first consideration. Moreover, modern elementary school programs call for an active program in all areas of the curriculum, and rooms must be arranged for multipurpose activities.

The same space that is needed for science can also serve for art, for social studies projects, for committee work of various kinds, and for group work in skill subjects that are now commonly accepted as phases of elementary school teaching procedure. The American Association of School Administrators has recommended, as a general rule, that modern classrooms should have about thirty square feet of space per pupil, exclusive of storage and accessory space.[1] This means that rooms with about 750 square feet of open floor space are needed for classes of twenty-five children. A room 30′ x 30′ is none too large. Furthermore, most of the furniture should be of the movable type, so that it can be pushed to one side whenever the program requires more open space. The room plan on page 163 is suggested for an elementary school classroom which can accommodate an average-size class of pupils.

Key to Facing Figure

1. Wardrobe
2. Storage cabinet
3. Workbench
4. Animal cages
5. Work counter
6. Sink
7. Formica top
8. Plants
9. Heater
10. Laboratory bench (gas and electric outlets)
11. Teacher's closet
12. Wardrobe
13. Library and study area
14. Tack board
15. Project display area
16. Formal instruction area
17. Books
18. Aquarium
19. Chalk board
20. Desk
21. Filing cabinet
22. Hedge
23. Work table
24. Outdoor area for class
25. Garden area
26. School camp
27. School forest

The room plan has been adapted from one that appears in *American School Buildings*.[2] The changes that have been made include the addition of areas specifically designed for the care

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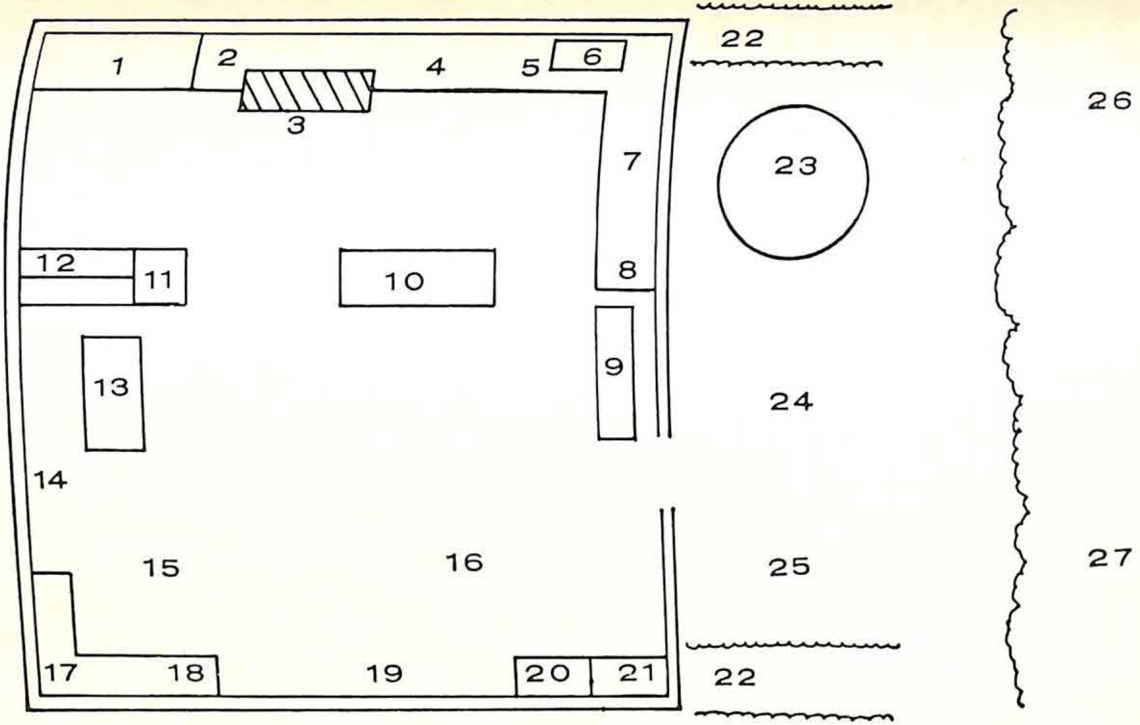
[1] American Association of School Administrators, *American School Buildings*, Twenty-seventh Yearbook (Washington, D.C.: The Association, 1949), pp. 88–89.

[2] *Ibid.*



SUGGESTED ROOM PLAN FOR AN ELEMENTARY SCHOOL CLASSROOM of living materials (plants, caged animals, and fish); a specially designed laboratory table with gas and electric outlets (a modern type, movable table is good); a work bench; and a counter top which provides for science work. These kinds of additions can be included in any of the modern classrooms. The outdoor area which is assigned to a classroom should be considered part of the permanent facilities of the classroom or school. The plan shown here makes such provision. This outdoor area should be supplemented by larger areas which are available to the teacher for use in other science projects. When they can be provided, school camps and forests make possible a much wider range of science activities.

Although not every class will always need or use its outdoor area all the time, such areas should be available. For groups studying plants and how they grow, weather and weather predictions, animal and plant habitats, rocks, minerals, and many other science topics which are related to an understanding of the environment, outdoor areas such as these are a virtual necessity. Placing the area next to the classroom means that the teacher can use the space when most convenient, and without disturbing other groups as the class goes about its activities. It is also important that the plot have good soil for planting, and that it be off traveled paths. The school camp and school forest, of course, cannot ordinarily be adjacent to the school, and their use generally depends on the availability of transportation.

In addition to the permanent facilities found in the classroom, the school also needs storage and repair facilities for its science (and audio-visual) equipment, shop space for the children, teachers, and consultants for work on large projects, and for projects requiring special tools. In some cases special science rooms are provided, but such facilities also serve the regular arts and crafts program. Adequate library provisions are, of course, essential for a good science program. The auditorium is also part of the needed science facilities, and it should be equipped for showing films to large groups, and also for assembly programs. To carry out their professional functions, teachers and science consultants need office space, desks, filing cabinets and other office equipment.

EQUIPMENT AND SUPPLIES

Permanent equipment should, in general, be of two types. First, there should be certain items that are provided in each room. These materials are not particularly expensive, and they can make a big difference in the quality of the science program. Second, many pieces of equipment are needed only on occasion, and can be shared by all the classes. Such items (microprojectors are a good example) should be stored in some central place in the school and charged out by individual classes as they are required. It is important that these items be readily available, however, and it is wise to have some one person responsible for seeing to it that teachers know how to use the apparatus, and for insuring that needed repairs are made. When there is a science consultant in the school, this is one of his duties. When no such consultant is on the staff, some other person should be designated for the task.

Supplies of an expendable nature are also needed for the science program. When a dry cell is no longer functional, it must be replaced. When a class uses a package of blueprint paper, it cannot be reused. Chemicals, wire, nails, and clay also must be available when needed. It is wise for a school to have a small petty cash budget so that teachers and consultants can easily purchase cheap items when occasion arises. Major purchases of expendable supplies must be made in an organized way, and should follow the same purchase procedures that are employed in obtaining other school supplies.

In the list[3] of equipment and supplies which follows, those items marked with an asterisk should appear in every classroom. All other items should be available from the central supply room.

[3] Harold E. Tannenbaum and Nathan Stillman, *Science Education for Elementary School Teachers*, pp. 269–274. Copyright 1960 by Allyn and Bacon, Inc., Boston, Massachusetts. Reprinted by permission of the publisher.

EQUIPMENT AND SUPPLY LIST

- Aneroid barometers
- Thermometers
  - *Outdoor thermometers
  - *Room thermometers
  - Clinical thermometers
  - Chemical thermometers (Fahrenheit and centigrade)
  - Cooking thermometers
  - Air thermometers
- Hydrometers, heavy and light liquid
- Graduated cylinders (assorted sizes; both English and metric markings)
- Scales
  - Two-pan balances
  - Spring balances
  - Kitchen scales
  - Bathroom scales
  - Weights (both metric and avoirdupois)
- Air pumps (compression and vacuum)
- Battery jars
- Bell jars
- Anatomic models
  - Human torso
  - Human eye
  - Human skeleton
- Color wheels
- Prisms
- Lenses, assorted; including:
  - Concave lenses
  - Convex lenses
  - Old eyeglasses
- *Magnifying glasses
- Mirrors
  - *Plane mirrors
  - Curved mirrors
- Microscopes
  - Slides
  - Cover slips
  - Lens paper
- Microprojectors
- Tuning forks (assorted frequencies)
- Wires of assorted thicknesses and lengths (for sound)
- Dry cells (assorted; including storage batteries)
  - *1.5 volt cells
  - *Flashlight batteries
  - (Be sure to keep some dead cells for children to break open and examine)
- Wire, assorted; including:
  - *Bell wire
  - Heavy insulated wire
  - Zip cord (used on household appliances)
- Switches, assorted, including:
  - *Knife switches (assorted, including single pole, single throw; single pole, double throw; double pole, single throw; double pole, double throw)
  - Toggle switches
  - Push button switches
  - Pull chain switches (on lamp sockets)
  - Twist switches (on lamp sockets)
- Sockets, assorted; including:
  - *Miniature sockets (for flashlight bulbs)
  - Standard base sockets
  - Fluorescent fixtures

- Bulbs, assorted, including:
  - *Flashlight bulbs (for use with 1, 2, and 3 cells)
  - Standard base (assorted wattages; some clear glass)
  - Fluorescent bulbs
- Fuses, assorted
- Electric wall plugs
- Friction tape
- Extension cords
- Soldering irons
- Solder
- Galvanometers
- Rheostats
- Spark coils
- Telegraph sets
- Telephones
- Doorbells
- Magneto or generator model
- Radio equipment
  - Antenna coil (standard broadcast band)
  - Antenna wire
  - Variable condensers (365 mmf)
  - Fahnestock clips
  - Head phones
  - Old radio parts (including tubes, speakers)
  - Crystals and ticklers
- Magnets
  - *Bar magnets
  - *Horseshoe magnets
  - Alnico magnets
  - Floating magnets
  - Electromagnets
- Large nails (for making magnets)
- Iron filings
- Compasses
  - *Magnetic compasses
  - Free needle compasses
- St. Louis motor
- Electrolysis apparatus
- Model steam engines
- Model machines (which can be hitched up to steam engines)
- Pump models (lift and force)
- Pulleys, assorted; including:
  - *Single pulleys
  - Double, triple, and quadruple pulleys
  - Tandem pulleys
- Gasoline engines
  - Demonstration model gasoline engines
  - Old lawn mower engines
  - Model airplane engines
- Radiometers
- Thermostats
  - Bimetallic thermostats
  - Thermostatic switches
- Photography equipment
  - Pin-hole cameras
  - Lens cameras
  - Daylight paper
  - Blueprint paper
  - Prepared developers and fixatives
  - Trays
- Rock and mineral collections
- Shell collections
- Seed collections
- Insect collections (including cocoons and egg cases)
- Clocks (for the children to take apart and examine)
  - Pendulum clocks
  - Spring clocks
  - Striking clocks and alarm clocks
  - Electric clocks
- Old household appliances
  - Irons
  - Toasters
  - Mixers
  - Fans
  - Beaters
  - Vacuum cleaners

Soil testing kit
Test tubes (assorted sizes, both pyrex and soft glass)
Test tube brushes
Test tube racks
Test tube holders
Flasks (assorted sizes and shapes)
Beakers (assorted sizes)
Evaporating dishes
Filter paper
*Pans
*Jars
*Glasses
*Spoons
Tongs
Wire gauze
Iron extension rings
Ring stands
*Asbestos pads
Bunsen burners (use burners with attached bottle gas if piped gas is not available in school)
*Electric hot plates
Clamps (assorted)
Pinch cocks
Thistle tubes
Funnels
Rubber stoppers (one- and two-hole in assorted sizes)
Corks (assorted)
Rubber hosing (assorted sizes)
Glass tubing (assorted sizes, including thermometer tubing, barometer tubing, large bore tubing)
  T tubes
  Y tubes
Pneumatic troughs
Thin rubber sheeting
Mortars and pestles
Crucibles
Glass squares
Petri dishes
Blowpipes
*Medicine droppers
Plaster of Paris
Cement
*Modeling clay
Hand tools
  *Screw drivers
  *Hammers
  *Pliers
  Chisels
  *Saws
  Mallets
  Tin snips
  *Files
*Nails and screws (assorted)
*Colored paper and cellophane
*Candles
*Straws
*Brushes (both water color and larger paint brushes)
*Water colors
*Colored inks
Food dyes
*Scissors
*Knives (particularly penknives)
*Pencils and pens
*Colored chalks and crayons
*Wood splints (tongue depressors and swab sticks can be used)
*Adhesive tape (both cellophane and cloth)
*Aluminum foil
*Pliofilm
*Pins
*Paper clips and fasteners
*Thumb tacks
*Rubber bands
*Labels
*Thread (strong sewing thread)
*Needles (both darning and metal knitting needles)
*String
*Sealing wax

*Paste
*Glue
*Protractors
*Drawing compasses
*Rulers (twelve- or eighteen-inch)
*Yardsticks
*Meter sticks
*Matches
*Balloons
*Marbles
*Flashlight
Dissecting kits
Deflagration spoons
Static electricity equipment, including:
  Rubber rods
  Glass rods
  Silk
  Fur
  Wool
  Pith balls
  Electrostatic toys
  Electroscopes
*Absorbent cotton
*Cardboard milk containers (half-pint and quart size)
*Tin cans (assorted sizes)
*Wooden boxes (assorted sizes)
*Globe
Geodetic survey and three-dimensional maps (especially of local area)
Wire netting
*Aquaria
*Terraria
Ant houses
*First aid kits
*Blankets
Sand buckets
*Fire extinguishers
*Flower pots
*Watering cans
Hydroponic materials for plants
Spades
*Trowels
Soil (it's hard to get when the ground is frozen)
Gravel
Star charts
Models of the solar system
*Rubber balls (various sizes)
Pieces of wood
Pieces of metal
Enameled pans
Egg beaters
Sauce pans
Kettles
Pinwheels
Strainers
*Rubber gloves
*Can openers
Salt
Cane sugar
Grape sugar
Baking soda (sodium bicarbonate)
Baking powder
Rice, white and brown
Lima beans
Kidney beans
Cornstarch
Flour
Gum arabic
Paraffin
Steel wool
Vaseline
Corn oil
Sand
Charcoal
Lamp black
Litmus paper
Kerosene
Vinegar
Turpentine
Gasoline
Machine oil

Chemicals
  - Alcohol
  - Acetic acid
  - Benedict's solution
  - Benzine
  - Boric acid
  - Bromthymol blue
  - Carbon disulphide
  - Carbon tetrachloride
  - Ferric chloride
  - Formaldehyde
  - Glycerin
  - Hydrogen peroxide
  - Iodine solution
  - Lead nitrate
  - Lime water
  - Phenolphthalein solution
  - Potassium permanganate
  - Ammonia water
  - Sodium thiosulfate (Hypo)
  - Fehling's solution
  - Concentrated and dilute nitric acid
  - Concentrated and dilute sulphuric acid
  - Concentrated and dilute hydrochloric acid
  - Calcium carbonate (marble chips)
  - Chromium oxide
  - Cobalt chloride
  - Copper (metal strips)
  - Copper sulfate
  - Iron chloride
  - Iron sulfate
  - Iron oxide
  - Iodine crystals
  - Lead
  - Lead nitrate
  - Manganese dioxide
  - Mercury
  - Mercuric oxide
  - Nickel sulfate
  - Potassium chlorate
  - Sodium hydroxide
  - Strontium nitrate
  - Sulfur
  - Tin
  - Zinc
  - Zinc chloride

TEACHING AIDS

The fourth area of needed facilities includes teaching aids. Books, periodicals, maps, charts, films and filmstrips are needed for the science program. Pupils also need science textbooks and reference books. Each classroom, in its library corner, should have a supply of appropriate science trade books, some standard reference works, several texts from other grade levels, and some periodicals. Good dictionaries are essential, and there should be at least one adult dictionary. The school library, of course, should have many more books in all areas of science, encyclopedias, and files of maps, charts, pamphlets, and other reference materials. These references should be kept current and should also be circulated to the classrooms where they are being used.

In addition to these materials for the pupils, the library should provide reference facilities for the teachers in the form of books on science education, books on science for adults, such current periodicals as *The Science Teacher, School Science and Mathematics, Scientific American, Science Newsletter, Science Education,* and the *Elementary Science Bulletin.* The following criteria can be of some help in the selection of science reference materials:

1. The information should be scientifically accurate.
2. The materials should have literary merit.
3. The materials should be appropriate for children.
4. The materials should be up to date.

Many lists of books and references are available. Among the best are the book lists provided by the National Science Teachers Association and the American Association for the Advancement of Science.

Chapter Six

EVALUATION

"Evaluation is the complex system through which a teacher establishes judgments and makes decisions about his students, his program, and his teaching." [1] There are two major, closely interrelated, aspects to an effective program of evaluation: (1) the growth and development of children in science: to what extent have individual children grown and developed in terms of the understandings, attitudes, and skills encompassed by the statement of goals for elementary school science? and (2) the effectiveness of the elementary school science program: to what extent have the flexible and planned science programs, the various approaches to teaching, the materials and equipment, and the administrative organization made it possible for children to learn? In this chapter we suggest ways in which teachers, consultants, and administrators can evaluate child growth and the general effectiveness of the program.

Evaluation involves both the collection of data and the placing of value upon the data collected. The mere collection of data is difficult at times, because it is hard to determine what some of our goals for elementary school science mean in terms of child behavior. For example, what kind of behavior will indicate that a child has gained an understanding and some skill in using the methods of science? The evaluation of the various kinds of data that are collected can be even more demanding. What is the importance, for example, of a child's verbal statements with regard to an elementary school science goal?[2] But with relevant data whose relative value has been properly adjudged, the teacher has a basis for making decisions about his students, his program, and his teaching.

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[1] Harold E. Tannenbaum and Nathan Stillman, *Science Education for Elementary School Teachers* (Boston, Massachusetts: Allyn and Bacon, 1960), p. 222.

The major purposes of evaluation are to determine the relative effectiveness of the educational experiences that our children have, and to find ways that our programs can be improved. Too often, evaluation has been viewed as judgment of the relative success or failure of individual pupils. To paraphrase the ancient proverb, "Judge so that ye be judged." Children have experiences in science in order that they may move a little farther along the paths toward the goals that have been outlined. We evaluate to see whether they have taken any steps along these paths, and to find out whether there are other and better ways that we might employ to move them forward a little farther and faster.

EVALUATION OF GROWTH AND DEVELOPMENT IN SCIENCE

The evaluation of a child's growth and development should be done in terms of the goals that have been set up for the program of elementary school science. In this monograph, for example, we have suggested five general goals. Goals, however, have to be delineated into more specific statements that describe the patterns of behavior that we want children to develop. In the process of evaluation, the actual behavior patterns of children are compared with those that are to be desired.

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[2] In a study of the relationships between children's verbal statements with regard to desirable conservation behavior and their observed behavior Trexler found little correlation between the two. Is there a similar lack of correlation between children's statements and actual behavior in other areas of science? Some of our suggestions for obtaining data for evaluation have been obtained from this study. Clarence R. Trexler, *Conservation Behavior of Children in an Urban Classroom* (New York: Unpublished doctoral project, Teachers College, Columbia University, 1959).

A number of information-gathering procedures, methods of observation, and testing devices have been developed that can be used to obtain some of the information that is needed for evaluation in elementary school science. The following are some promising ways to obtain these data: [3]

1. *Anecdotal records.* Anecdotal records are records of a child's comments and behavior relative to some goal of elementary school science. The anecdotes should be jotted down as soon as possible after the observation has been made. Anecdotal records are especially valuable to show changes in behavior over a period of time.
2. *Tests.* Various kinds of tests are useful instruments for eliciting information about what children know or do not know. By imaginative development of test items, valuable information with regard to many of the goals of the science program can be obtained. Standardized tests can help the teacher to compare the growth of his group of children with those elsewhere.
3. *Observational check lists.* When certain specific kinds of behavior are to be looked for, check lists of behavior make it easier for the teacher to record that behavior.
4. *Children's writings.* In the intermediate and upper elementary grades, children's writings have proved to be a rich source of information with regard to the concepts they hold of the world in which they live. Children are often able to express ideas and concepts in writing that would not be elicited by various kinds of tests.
5. *Tape recordings.* Tape recordings provide verbatim accounts of class discussions. These can be analyzed to determine the concepts that individual children have with regard to science generalizations.

The information that is gathered has to be analyzed in terms of the goals of elementary science. The following are some suggestions for the analysis of information in terms of the five goals suggested in this monograph.

Building a world view that is consistent with the modern

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[3] Some of the suggested techniques for gathering information have been drawn from John Garone, *Acquiring Knowledge and Attaining Understanding of Children's Scientific Concept Development* (New York: Unpublished doctoral project, Teachers College, Columbia University, 1958).

scientific world view. Probably the best way to obtain information for evaluation of growth toward this goal is to provide ways for pupils to express their concepts freely. Children's writings are especially revealing of their concepts. One group of children, for example, was asked to write a short statement in reply to the question, "What do you think outer space is like?" Their replies represented a wide range of concepts: "Space is infinite"; "There is a definite end to space"; "Outer space is empty"; "There is a great deal of dust in outer space"; "It is extremely cold in outer space"; "The temperatures are very high in outer space." Similar kinds of information can be obtained from group discussions and individual conferences. With young children in the lower grades, discussions and conferences become the prime source of information.

Information that is obtained from children's writings, discussions and conferences is compared with the best available information we have about any particular aspect of the environment. For example, the children's views of the nature of outer space can be compared with the latest and most reliable scientific information.

In evaluating the extent to which children have developed a defensible world view, particular attention should be accorded such questions as the following:

1. Is man related to the rest of the living world, or is he set apart from it?
2. Is the universe viewed as being relatively vast or relatively small?
3. Is the universe viewed as a challenge for exploration and investigation, or do we already know enough about it?
4. Where do we look for authoritative information about the world in which we live?
5. How can we learn of new information with regard to the nature of the universe?

Gaining an understanding and some skill in using the methods of science. The methods and approaches of science are of value to us in dealing with perplexing questions and difficult problems, and we can best evaluate children's understandings and skills as we see them dealing with problem situations. A group of first-grade children, for example, could not get the flashlight bulbs in a doll house to work. The teacher observed the various steps they went through before they found that one bulb was not screwed in tightly enough. These children did not try to check the entire doll house at once. Instead, they tested one hypothesis after another until they found how to make the bulbs light.

At other times, teachers pose questions for children in order to see how they go about finding answers. One teacher, for instance, asked, "Which will fall to the floor most quickly when dropped, a steel ball or a wad of paper of the same size?" By observing how they clarified the question, proceeded to set up an experiment, carried out the experiment, and checked their results with the results obtained by others, she was able to get considerable insight into the children's understanding of the methods of science and their skill in using them.

In evaluating the understandings and skills related to this goal of science, special attention should be given to such questions as the following:

1. Do children attempt to clarify and define the question or problem before undertaking experiments or making observations?
2. Do children check to see what is known about a problem or question? Do they try to find out what experiences others have had in dealing with similar problems?
3. Are fruitful hypotheses suggested that can be tested by experimentation and observation?
4. What do the children consider to be the most reliable and valid sources of information?
5. Do the children check the results of their experimentation and observation with the major generalizations that have been developed in science?
6. Are the children able to use the results of their investigations to deal with questions or problems?

Developing the ability to understand and appreciate the many current advances in science and technology. To help children and young people to read about developments in science and technology with understanding and comprehension, a certain degree of scientific literacy has to be developed. Vocabulary checks are one of the ways to evaluate growth in ability to understand scientific terms. A better approach is to determine children's comprehension of written materials, radio programs, and films. Through group discussions and short tests based on the science material that has been read, heard, or viewed, the teacher may learn the extent to which children understand it.

But it is not enough for children to have the ability to read, view, and listen with understanding; they should also develop the habit of actually reading books and articles dealing with science and viewing or listening to science programs. In the flexible dimension of the elementary school science program the teacher will discuss timely topics in science, review recent articles, programs, and children's books and, in the process, learn more about the extent to which the children try to keep informed.

1. Do the children listen to and view important science programs on radio and television? What kinds of programs?
2. Do the children read science books written for children? What kinds of books do they read?
3. Are the children able to understand the science materials which they read?
4. Have the children developed habits that will help them to keep informed of developments in science and technology?

Learning how to achieve optimum physical health. Are the children healthy? This is the basic test to be used in evaluating this goal of elementary school science. Although good education cannot cure all ills, it should show children how to maintain and improve their health. In this particular case verbalizations and good intentions are not sufficient; the basic habits of body care that lead to good health and optimum growth and development must be inculcated.

In most schools, basic data are available which will give some background on the health status of the pupils. Daily attendance records give some indication of how often a child is sick. The school nurse's graph of height and weight records over a period of time show whether a child's growth approximates a general pattern or whether, for some reason, growth has been arrested.

There are a number of ways to check on children's eating habits. In the school lunchroom an observant teacher can note whether they are actually eating the kinds of foods that make up a good lunch. Through a study of dietary records kept by older children, and interviews with children too young to keep records, it is possible to determine whether or not they are receiving an adequate diet.

The sensitive observer can readily note the differences between the hale and hearty child and the child who is near-to-ill. The glistening hair, bright eyes, glowing cheeks, and energetic exuberance of a healthy youngster is a picture that all teachers should have in mind. A deviation from this picture should lead a teacher to ask, "Can anything be done?"

1. Do all the children in the class give the appearance of being healthy?
2. In the course of a day, do the children eat the kinds of foods that are essential for an adequate diet?
3. Do the graphs of height and weight records approximate the usual growth patterns? If not, what are some possible explanations for the discrepancies?
4. Have the children developed habits that tend to prevent the spread of disease?
5. What are some of the common causes of illness in the class? How could the illnesses be prevented?

Learning how to participate effectively in future policy-making on issues that involve science and technology. The future citizens of a community, state, and nation need to prepare to shoulder the responsibilities of citizenship, and to meet these responsibilities they must have some familiarity with the science and technology involved in the basic issues that they will face. How are our children faring in their preparation?

The best way to evaluate progress toward this goal is to have the children consider the important issues that now face citizens. A significant feature of the flexible dimension of the elementary school science program is the consideration of current issues on the local, state, and national scenes. We can evaluate the children's progress by noting how they approach and deal with these issues, and the solutions which they suggest.

1. Do they recognize the kinds of information that are needed to resolve the issues? Do they have the background and skill to obtain the needed information?
2. Do they use the approaches of science to deal with problems? For example, do they suggest reasonable hypotheses that can be tested?
3. Are they willing and able to seek information from a variety of sources?
4. Do they respect the ideas of others even though these ideas may initially be opposed to their own?
5. Do they maintain a balance between the practical and the visionary in suggesting hypotheses?
6. Are they concerned about public problems and issues?

EVALUATION OF THE SCIENCE PROGRAM

The general effectiveness of the elementary school science program should be studied. The purpose of such an evaluation is to improve the program so that the children will have better experiences in science. The survey includes an appraisal of the general planning for science experiences; the nature of the experiences the children actually had as contrasted to those that were planned; the approaches and methods used by teachers and consultants; the use of materials and equipment; and the procedures that were used to evaluate child growth and development. In the evaluation of the elementary school science program, teachers, science consultants, and administrators take a look at what they have done to see how they might do better in the future.

This evaluation is a continuing process in which all the people who have professional responsibility for the program should take part. The teacher, after a lesson, may in retrospect consider how the lesson might have been conducted better. The science consultant, at the close of a unit of study, may note ways in which the approach to the unit can be improved; the principal may ask himself how he can make available the materials and resources that are essential for an effective program; and at various times all of them may gather together and ask themselves, "How can our work in science be improved?" The following are some guidelines for the evaluation of the elementary school science program.

GUIDELINES FOR THE EVALUATION OF THE SCIENCE PROGRAM

Children's Interests. Were the children interested in the science activities that were undertaken? Of perhaps greater importance, do they continue to be interested in science? To a certain extent, elementary school science activities should be developed from the expressed interests of children. Certainly, the experiences children have in science should nurture and stimulate their continued interest.

Children's Experiences. What was the nature of the experiences the children actually had as contrasted with those that were planned? What did the children think of the experiences? The experiences that children actually have are often at variance with the outcomes that were expected from the activities that were planned. The children's actual experiences are what count.

K–12 Science Program. Did the science experiences that a group of children had contribute to the goals of the over-all science program? Were the experiences articulated with those planned for other grades in the school? The science experiences of any particular group of children should be evaluated in terms of their contribution to the K–12 science program.

General Program. Did the science experiences contribute to the over-all goals of the elementary school? The science experiences of any particular group of children should be articulated with the experiences they have in other areas of the curriculum as well as with the K–12 science program.

Balanced Content. Did the children have some experiences in each of the six major areas of science during the school year? One of the major attributes of the planned elementary school science program suggested in this monograph is that children will have experiences in depth in each of the six major areas of science during the course of a year.

Variety of Approaches. Was a variety of approaches used in teaching? In science it is possible to use a variety of approaches such as experimentation, demonstrations, field trips, library investigation, and project work, and these opportunities should be capitalized upon.

Flexibility. Were the children able to deal with the science-related topics as they occurred? Some of the goals of elementary school science programs can only be achieved if the flexible dimension of the program makes possible the consideration of current issues and topics.

Equipment and Materials. Did the children have many opportunities to handle the equipment, apparatus, and materials of science? One of the essential characteristics of a good elementary school science program is that children have abundant opportunities to handle science materials.

Individual Differences. Were science activities planned to meet the varying needs and interests of children having the wide range of abilities often found in classroom groups? If our aim is to help each individual child achieve optimum development in science, then we must take cognizance of the differences among children as we plan science activities.

Continued Evaluation. Was there periodic evaluation of the science activities undertaken? Were changes made in the program as a result of this evaluation?

Self-improvement. Did the teachers, the science consultants, and the school administrators make a deliberate effort to improve their work with children in science? Science is one of the most dynamic and rapidly changing fields of human endeavor; in this field, to stand still is to court disaster.

Chapter Seven

ELEMENTARY SCHOOL SCIENCE FOR TOMORROW

Then what of the future of elementary science? Obviously we must look both at immediate problems and prospects that lie ahead. Furthermore, there must be a clear path which will take us from our present state to a condition which better fits the needs of our children and of the nation insofar as science programs are concerned. We must consider the prospects in terms of personnel, equipment, supplies, and curriculum. First, let us examine the problems and courses of action with regard to personnel.

There are two aspects to the work to be done with professional personnel. In the first place, there is the continuing need for well-planned and continuous in-service programs, workshops, and graduate courses. These activities should tend to raise the level of competency of our work in science. Second, we must institute better preservice courses and programs which will insure improved teaching of science by the new recruits of the profession.

In-service programs. Teachers face difficult problems in preparing themselves to work with children in science and in keeping up to date in elementary school science. Among them are the following:

1. The foremost problem is fear: fear of using various kinds of science materials; fear of being embarrassed by bright pupils or of not knowing the answers to too many questions; fear of the consequences of "too much science."
2. Then there is the problem of not understanding the nature of science. For so many people, "science" is a set of pat answers to a number of fixed questions; it is more like a catechism than an exciting exploration of a world of unknowns.
3. Finally, there is the problem of lack of science information, and a compounding difficulty of not knowing ways to obtain such information. Even when teachers have studied in various science courses, their information is often very much out of date. Furthermore, elementary school teachers often have had little or no experience with the physical sciences or the earth sciences.

Resolving these difficulties involves many activities. First, we must capitalize on the two very positive factors which exist in our present situation. These facts stand out:

1. Elementary school teachers, on the whole, are an enthusiastic, willing, and dedicated group. They love their work and are devoted to the profession and to children.
2. Elementary school teachers recognize the profound interests which children have in science; they recognize the need of society for scientific literacy; most of all, they recognize their own weaknesses in the area, look for leadership, and seize every opportunity to improve themselves in their science work.

These positive forces are being used throughout the nation in building in-service programs.

Courses in elementary school science. In a recent survey of some of the goals and procedures in professional courses in elementary school science, the major goal found was that of helping elementary school teachers gain a clearer picture of the nature of the scientific enterprise. Teachers need to see science as a way of inquiry into the natural, physical world in which they and the children live. As a result of this need, the courses that these science educators have established take the students through numerous experiences of "sciencing." In other words, these courses require active participation in dealing with science problems by clarifying the problems; looking for answers in a variety of ways (through reference work; experiments; experiences with tools and instruments; trips; and audio-visual materials); and looking for the significance of the answers which have been found.

There is another important characteristic common to many of these science education courses. They deal with both the content of science and methods used to develop science experiences with children. In other words, the courses are built around the teaching and learning of major science generalizations *and* the ways in which such generalizations are used in developing and implementing science programs.

Although it is true that there is no common agreement as to the exact nature of the content to be presented in such courses, there is usually more emphasis on the physical and earth sciences than the biological sciences. This is because most elementary school teachers are believed to have a weaker background in the physical sciences. There is definite effort on the part of science educators to remove the deficiency in the elementary school science program caused by teachers' fears and lack of information.

Teacher workshops in elementary school science. Again, as in the case of in-service courses, a growing and expanding program of elementary school science workshops is in evidence. School systems the nation over have instituted workshops in which the elementary teachers of a given system have been brought together for work in science. In some communities the leadership has come from personnel of the system itself. In others, outside consultants from state education departments, or from various colleges and universities have been brought to the workshops to lead the teachers in their efforts to find better ways to develop science experiences. The variations in content, in organization, and in stress have been wide. Sometimes the workshops meet to try to agree on scope and sequence for a curriculum. Sometimes they meet to find ways to build an active, experimental program. At other times they are concerned with new techniques for developing various kinds of science activities in the classroom. Workshops have been found to be an effective way of getting teachers to work together to improve programs in science for children.

Science curriculum committees. Because of growing concern about science in the elementary school program, many communities have found it desirable to set up a standing curriculum committee in science. Teachers from all levels are brought together to examine and evaluate existing programs, and to plan and institute new programs based on what seems best for the children of a given district. Very often, these committees include elementary school science consultants or supervisors, and these consultants provide the leadership in curriculum revision and in helping classroom teachers with their science programs.[1] These curriculum committees are also being established as permanent and continuing committees which have the responsibility not only for writing the original curriculum, but also for continuous reevaluation of what has been written, and for helping all teachers, and especially new teachers, to find better ways to implement the curriculum in their classrooms.

Preservice teacher education. In essence, the objectives of the preservice programs and the in-service programs are the same. We want more effective teachers of science in elementary schools. This means that we must do two things for young people who are coming into the teaching profession. In the first place, we must increase the number of opportunities they have to study science. In fact, we must increase the amount of time that they spend in receiving their education generally. Second, we must improve the quality of the educational experiences in which our future teachers take part. These young professionals must be literate in the full meaning of the word if we are to have the kinds of teachers we need for tomorrow's schools, and this necessarily implies literacy in the field of science.

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[1] Such consultants are not always ideally fitted for the task assigned. In many cases the consultant is a high school science teacher who is released from part or all of his high school assignment to act as "consultant" to the elementary school teachers. Sometimes this works out well. In other cases, however, because the so-called consultants know little about elementary school children and how they learn, and have no knowledge of the purposes and functions of elementary school science, the programs are hindered rather than helped.

In the near future almost all our regularly certified elementary school teachers will hold bachelor's degrees. But that is a minimum goal. Five-year preservice programs are now in existence, and are certain to become common in the next decade. Six-year preservice programs are on the way, and will replace the five-year programs in twenty years or less.

What will go into these programs? A well-rounded general education, a thorough professional education, and a period of carefully supervised internship will be foundational in many of them. In several plans, there is enough in common to suggest the following pattern for the six-year program:

1. Two thirds of the program devoted to general education
2. One sixth of the program devoted to professional education
3. One sixth of the program devoted to supervised internship

Several points are important:

First, and foremost, everyone agrees that the quality of both the general education courses and the professional courses must be of the highest order. Every course must be worthy of the time invested in it. Every course must move its students to the kind of scholarship required of the modern teacher.

Second, the entire program needs consideration. The education of every teacher, whether at the elementary, secondary, or college level, regardless of his ambitions and specialized areas of interest, needs to be a truly general education. The art specialist must have an intelligent understanding of science. The social studies specialist cannot be illiterate and uninformed in the arts, or in language, or in science. And, in addition to a substantial background in his area of specialization, the science specialist must be a literate, well-informed, and educated layman in all areas.

In the case of elementary school teachers, the need for a broad background of information in liberal studies is even more clear. Not only must the teacher have this background by way of being a well-educated person, but if we continue our practice of organizing "self-contained" classrooms, the elementary school teacher also needs the same information for strictly professional reasons, for the teacher will use this background information in day-to-day class work.

Third, the various liberal studies and the professional program must be seen as a unified entity. The preparation of a teacher must be one in which the general education (liberal studies) program and the professional education program are so articulated that the prospective teacher is able to use the experience to become a better person, a better citizen, and a better teacher.

One important warning should be noted: Each of these kinds of programs needs to be well prepared and scholarly, and all courses must be directed to the education of professionally competent teachers. Unifying the program does not mean that the liberal studies courses should become "watered down" and valueless "methods" courses. Nor does it mean that the professional courses can become offhand and unproductive secondary portions of the liberal studies offering.

Although no exact specifications can be given for the various phases of preservice education of elementary school teachers, the following are some suggested goals for their studies in the various areas of the curriculum:

THE HUMANITIES

1. Developing skills in communication to a high degree of competency. This should include not only ability to read, to write, and to speak proficiently, but, even more important, the ability to organize and communicate ideas.

2. Developing an appreciation for the various arts such as music, painting, literature, and the dance, to the point that the prospective teacher can employ these art forms in daily life.

THE SOCIAL STUDIES

1. Developing an understanding of the nature of society and culture, including comprehension of the roles of anthropology and sociology in analyzing societies (including our own).
2. Clarifying the role of history in developing a perspective with which to view present local, national, and world developments.
3. Understanding the variations in world cultures, and learning about peoples and places that, while coming rapidly into world affairs, are none the less often left out of our studies. Asian, African, and Latin American cultures are most often in these categories.
4. Developing an awareness of the political structures and the economic forces which are part and parcel of our own nation's structure, and of the forces and institutions at work in other nations of the world.

THE NATURAL SCIENCES

1. Clarifying the major ways in which the natural environment is examined, analyzed, and understood. Students should gain an insight into the nature of science and the scientific enterprise, and a better understanding of the roles of science in contemporary society. Although there is no *single* scientific method, the total scientific enterprise has developed a number of highly useful methods and techniques for examining both phenomena and ideas. Among these are research techniques, laboratory techniques, the use of measurement and of quantitative data, and the employment of specialized language and symbols.
2. Developing an awareness of, and concern for, the vast heritage of information developed in the natural sciences, which has added new dimensions to life in the contemporary world. Here it is important that students develop understanding of

the significance of technology as well as appreciation of the advances in the so-called pure sciences.

THE PROFESSIONAL STUDIES

1. Developing a clear understanding of the role of the school in society, and of the variety of tasks assigned to the teacher.
2. Mastering the methods and techniques for working in the various subject areas of the elementary school curriculum. Certainly a teacher must know what to teach, but he will be ineffectual unless he also knows how to teach. Every elementary school teacher should have had a professional course in elementary school science.
3. Developing a comprehension of the nature of the child and learning how to build a sound school program based on an understanding of the relationship between the ways people learn and the materials they study.
4. Developing a clear understanding of the individual teacher's goals and objectives, and of the over-all social goals of a community. Along with this must come techniques for evaluating both the growth of individual children and the general program of the class and school.

The program is ambitious; the task is immense. Can it be accomplished in a six-year program? Or even a ten-year program? The answer to these questions is that we must try to come as close as may be possible to producing the kinds of teachers we need for *all* our schools and *all* our children. What we are aiming at is raising the entire base of the American cultural level, and in the decades ahead this must include raising the level of appreciation, understanding, and competency in science. Our experiments in mass education have achieved considerable success from a quantitative standpoint. Our next task is to raise the qualitative standards of universal, compulsory education to new and ever higher levels.

Over the next ten years, an atmosphere of science must pervade our school rooms. We must develop a literate science population, and among the first to become literate must be the elementary school teachers. To bring such science literacy into being and to help prospective elementary school teachers become competent in science will require a quality of teaching which is of a different character from that existing in most of our colleges. For elementary school teachers, both the science courses and the science education courses must be so designed that these teachers can achieve some understandings of the scientific enterprise, and also discover ways of teaching these ideas to children in the elementary schools.

The curriculum in elementary school science. In a very real sense, the future directions for elementary school science can be developed from ideas suggested in monographs of this kind. It must not be inferred that the authors feel they have found *the final answer* for curriculum problems in elementary school science. Far from it. The program which has been outlined in these pages is only one of many that could (and should) be tried. We have discussed the criteria on which elementary school science programs should be based; we hope there is general agreement about these criteria. In addition, we have accepted certain guidelines for the future of elementary science, which, to a certain extent, may influence trends in elementary school science programs. These guidelines are as follows:

1. The elementary school science program of both the immediate and the long-range future will be an essential and foundational part of the school curriculum. In the future it will be as unthinkable to consider eliminating science from the program as to consider not teaching reading or writing.
2. Elementary school science will be a basic element in the general education of children and, as such, will be taught to prepare a scientifically literate citizenry.
3. The elementary school science program will be a continuous and a unified program. A wide variety of science materials will be studied over the seven or eight years of elementary schooling; all these materials will help children and adults develop a rational, and unified picture of science.
4. The elementary school science program will be a program

of science and not just a program about science. The days of science teaching as extra lessons in reading or in social studies are numbered. Children will study elementary school science by carrying on the activities appropriate to the science being studied.

We hope that *Modern Elementary School Science* will be a source of ideas and a catalyst for action that will help elementary school teachers, science consultants, school administrators, parents, and others who are concerned with elementary science programs to make better and more challenging experiences in science a part of the birthright of children in our schools of tomorrow.

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